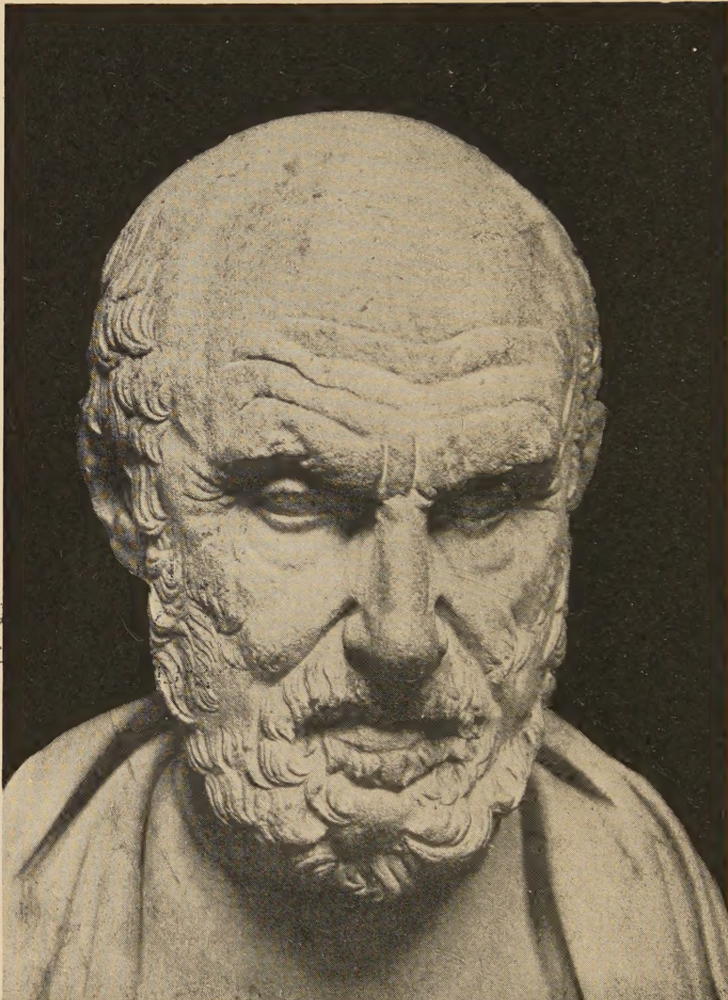
A SHORT
HISTORY OF MEDICINE



HIPPOCRATES

Ἦν γὰρ παρῇ φιλανθρωπίη πάρεστι καὶ φιλοτεχνίη.
Where the love of man is, there also is love of this Art.

Παραγγελίαι, i.e. *Precepts* (Hippocratic Collection), § 6

A SHORT HISTORY OF MEDICINE

INTRODUCING MEDICAL PRINCIPLES TO STUDENTS AND NON-MEDICAL READERS

BY

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Scire potestates herbarum usumque medendi
Maluit et mutas agitare inglorius artes.

It was his part to learn of the power of Medicine and of the manner of healing and, heedless of glory, to exercise that quiet art.

Virgil, *Aeneid* xii. 396–7

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PREFACE

THE position that Medical Science has now assumed in the social polity demands that all educated men and women should have some knowledge of the subject, whether they have had a medical training or no. In these pages the author seeks to place before the reader, who is without special knowledge, some account of Medicine as a Science. For this purpose the historical method is peculiarly suited, since it recapitulates, in some measure, the actual stages through which each learner must pass. Though the story told here opens with Greek times, the narrative of the earlier period is so condensed that more than half the book is devoted to modern Medicine, which is presented as a natural outgrowth of an ancient tradition. An attempt has been made to keep the account as simple and as elementary as possible and to make the smallest demands on the scientific equipment of the reader. The slight divergence, in some matters, of the interests of American and of English readers, has been held in mind, so that, it is hoped, the book may be useful to both classes.

Throughout the work two particular aims have been steadily kept in view: first, to stress the principles of Medicine rather than the details of practice; second, to treat of those principles in as small a space as may be. For 'principles' the author has substituted at times the

word 'Philosophy'. He would, however, beseech the timid reader to take no alarm at a word, for he employs the term 'Philosophy' in a time-honoured fashion, and he undertakes not to plunge deep into the labyrinth of Metaphysic. The Philosophy of Medicine stands here for the disinterested study of the theory of the subject, without reference to its application to particular instances.

Certain omissions in the book are justified by the author's forthcoming publication of a history of the biological sciences treated along somewhat similar lines. It has thus, for example, seemed superfluous to include here any but casual references to such highly important topics as the study of hereditary characters or the experimental investigation of developmental defects. It is, however, the duty of the author to direct attention to certain other omissions necessitated by the compression of the work into a small compass. The history of Medicine, as here treated, is essentially a history of ideas. The personal element has been kept wholly in the background and very little space has been allotted to biographical matter. Nor do the limits of the book permit any discussion of the status of medical men, and very little even of their training. On this account many who in their day were remarkable rather for the influence they exerted than for the advances in knowledge which they initiated find no commemoration here. This line of treatment has involved omission of reference to those

teachers to whom the author himself owes most, Sir William Osler and Sir Clifford Allbutt.

A work on Medicine must be coloured, in some degree, by its author's conception of the nature of Life. On this theme there are divers views, for the full discussion of which there is here no place. The author professes himself, however, an adherent of a school of thought that is not, at present, greatly in fashion. He ranges himself as a vitalist under the banner of Aristotle and as a follower in the goodly company of Harvey, Hunter and Virchow, of Claude Bernard and Johannes Müller. He believes that there is a principle in living things that cannot be expressed in chemical or physical terms. He believes that this principle works to an intelligible end, that it is an *Entelechy*, an indwelling purposiveness, and that it is as real a thing as anything that is.

They are right who hold 'soul' to be not independent of body and yet not a kind of body. 'Soul' is not body but something pertaining to the body and dwelling therein, and, what is more, specific to each body. Our forebears erred in seeking to fit the 'soul' into a body without regard to the nature and qualities of the body, for the association of 'soul' and body is by no means thus at random. And so indeed we might expect, for the 'Entelechy' of each being comes naturally to be developed in the potentiality of each being, that is to say in the matter proper to it. Whence is manifest that the 'soul' is a certain 'Entelechy,' a notion

or form of that which has capacity to be endowed with 'soul'. Aristotle, *Περὶ Ψυχῆς*, *II*, § 2.

The author is well aware that this conception is neither useful nor helpful for physiological research in the present state of our knowledge. That is a very good reason for excluding it, as the vitalist Claude Bernard excluded it, from the physiological laboratory. But it is not a good reason for abandoning a point of view which does something to make existence intelligible. On the contrary, turning from the physiological laboratory to the living being as a whole, it is just the indwelling purposiveness that is, before all things, most worthy of consideration. Every function, every structure, every instinct, habit, or reflex, every mental activity that is related to health—and which is not?—may throw some light thereon. It appears to the author that the scientific method is by far the mightiest weapon that has as yet come within man's grasp, for the illumination of these multitudinous entities. The searching accuracy and power of that superb instrument, wielded by human reason in the quest of human health, is the theme of this volume. And yet, notwithstanding its triumphs, the experimental method, as applied in the separate sciences, has, of its nature, certain limitations with reference to living beings in general and living human beings in particular.

It is the business of each of the sciences—it is indeed an essential part of the method of Science—to separate

a circumscribed part of the Universe for consideration in and for itself. Men of Science must thus perforce become Chemists, Physicists, Astronomers, Botanists, Cytologists, Statisticians, and the like. In this respect modern *Science* differs most profoundly from medieval *Scientia* and from ancient *Philosophia*. 'Specialization' follows modern *Science* as shadow follows substance. The new method has triumphed wonderfully in these last centuries and it is mere folly and obscurantism to seek to place intellectual stumbling-blocks in its path. Nor must we be afraid of shadows. The author does plead, however, that, while the Man of Science must, from the very nature of his method, cut off part of his universe of experience from all other parts, he should bear in mind, when not employed on his special task, that he has so cut off and isolated his special experience, of deliberate and set intent. To bear this fact in mind should not mean and must not mean that Science fails to influence our view of the world as a whole, but it should mean and must mean the basing of our view of the world as a whole on experience as a whole, and not on an artificially separated fragment of experience. For Man is neither a walking test-tube, nor a living anatomy, nor a colony of cells, nor a self-repairing machine that carries its own spare parts, nor a mere summation of the factors of heredity and environment, nor, for that matter, is he a disembodied spirit. But he is a being with a purpose. Of that purpose he, of his nature, can

know very little, since it is a part of that through which he knows. Yet some glimpse of that purpose, though seen through a mist and ever so dimly, we may perhaps gain from the view-point on which the stony tracks of the separate sciences do ultimately converge. If the separate sciences did not so conspire to one end, why should we ever bother our heads or weary our limbs over their steep ascents? Are there not rosier paths that we might tread?

Throughout this book, then, the ideal kept in view is the description of Medicine as a Rational Discipline involving many and perhaps all the sciences. Medicine is not now and never has been followed wholly in the scientific spirit. But it is the story of the scientific elements in Medicine which is here to be told, and other aspects are passed over with a silence which must not be interpreted as the silence of contempt.

No two men undertaking the task here outlined would make quite the same selections or allot emphasis in quite the same manner. Doubtless the author has erred by omission and by commission, through ignorance and through misconception, but he hopes that he has never erred through prejudice. The ideas that he recounts are those that present themselves to him as the most important and fruitful within the range of scientific Medicine, and he is prepared to revise his opinions both on matters of fact and on matters of stress. He will therefore be very grateful for any corrections or suggestions.

The number of names mentioned in the book has been reduced to the utmost limit that has seemed feasible. In recounting many episodes one name has often been taken as an example or type, and thus perhaps sometimes an injustice has been done to other workers, no less important but perhaps less typical. When modern times and living persons are reached the selection becomes not only difficult but also delicate, but the reader must remember that the names are not always chosen for their eminence but sometimes rather as typifying the various movements that have to be discussed. There is a further complication in that an attempt is here made to bring history right up to date. Very few names of living men are mentioned, though the work of many living men is discussed. Though the author has sought to refrain from passing any judgement on such latter-day conclusions the value of which does not seem to him clearly and firmly established, yet even this course in itself implies a judgement, and one in which he is even more likely to err than in other topics of which the book treats. Nevertheless, some such judgement seems necessary to make the book a coherent whole.

There are several from whom the author has had help in the writing of this book. Mrs. Singer has criticized every detail, and has considerably modified its form. No English writer on the History of Medicine can fail to refer to the great work of Lt.-Col. Fielding H. Garrison of the United States Army and of the

Library of Congress at Washington. The author of this book owes much to Lt.-Col. Garrison's splendid bibliography, but even more to constant correspondence, carried on now through a good many years, with the man who made it. He owes a similar debt to a very old-standing friendship with Dr. E. T. Withington of Oxford, to whom he takes the liberty of dedicating this book. Professor Graham Wallas, Emeritus Professor of Sociology in the University of London, and Professor J. C. Drummond, Professor of Biochemistry in the University of London, have both read the book in proof, and have made a number of suggestions and corrections. Help on special points has been given by Dr. Clark-Kennedy of Corpus Christi College, Cambridge, Dr. Raymond Crawfurd, Registrar of the Royal College of Physicians of London, Dr. J. W. Eyre, Professor of Bacteriology in the University of London, the Rev. Father J. R. Fletcher, who has the unusual distinction of being both a Priest and a Physician, Dr. K. Franklin of the Pharmacological Laboratory in the University of Oxford, and Dr. William Robson, Lecturer in Law in the University of London, as well as by the author's pupils Dr. Ivor Hart, Dr. J. F. Prendergast, Dr. Dorothy M. Turner and Mr. F. Prescott, M.Sc. To all of these the author would tender his grateful thanks.

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January, 1928.

CONTENTS

LIST OF ILLUSTRATIONS

I

ANCIENT GREECE

(TO ABOUT 300 B. C.)

§ 1. *Origins of Greek Medicine.*

SCIENTIFIC Medicine began with the Greeks. The Greeks not only started scientific Medicine upon its course, but also provided the substantial basic elements of our anatomy, physiology and pathology, and above all, perhaps, our conception of the bodily 'constitution', 'habit' or 'temperament'. It is from the Greeks that we derive almost all our medical nomenclature. When to this we add that our medical traditions are inherited through a direct and continuous chain from the Greek practitioners, it becomes evident that the debt that Medicine owes to this marvellous people is great indeed.

Now this debt has become associated with two or three great figures. The names Hippocrates, Aristotle, Galen, are familiar to all. Yet it is not always recognized that these men were but the representatives of a widely extended and long-lasting system. Greek Medicine was, in fact, like modern Medicine, the result of centuries of carefully recorded, collated and progressive research. Greek Medicine first assumed a scientific aspect with the Ionian and Italo-Greek philosophers at the very beginning of the sixth century B. C. It continued to make important advances until the death of Galen at the very end of the second century of the Christian era. Thus the life-span of progressive and scientific Medicine among the Greeks was no less than eight hundred years. With the most tolerant use

of the words 'scientific' and 'progressive', we can hardly place the beginnings of modern Medicine in Europe before the end of the fifteenth century. Thus our own system has only been developing its characteristic features for some four and a half centuries, which is but little more than half the course that Greek science ran.

It is evident, therefore, that we may have much to learn from the Greeks, not indeed in matters of actual fact or observation—for nearly all that is *directly* useful in their writings has been absorbed long ago into our medical literature—but in spirit and method. From a study of the character and course of Greek medical science we can gain hints of the snares and pitfalls and catastrophes into which the Art of Medicine may at times be led. Further, by study of the practice of Medicine under conditions so different from ours, we learn something of what is truly permanent in the Art of Healing. Lastly, by tracing the growth of the Science of Medicine, as it arose among the Greeks and as it died in the hands of their less worthy descendants, we may take alike example and warning. We may learn to distinguish the healthy and vigorous growth of a science from the stunted and deformed products that are often acclaimed, even in our own times, as Wisdom's final word to Man.

It has been said that, 'save the blind forces of Nature, nothing lives or moves which is not Greek in origin'. The saying needs modification, for there is a thing which still lives and moves that is not Greek in origin, a blind force which is not a blind force of Nature. It is the force of Superstition, of that age-old belief that Nature will give us something for nothing, which is

expressed by the word 'Magic'. The Greeks were no more free from that contemptible fallacy than are the men of our own days. But the greatest of the Greeks stood wholly above such folly, and we can watch the Greek mind gradually lifting itself from that primeval mental attitude which is older than any known culture, older perhaps than any known race, the attitude of Nature-Worship, or 'Animism'. To give an idea of how the 'sweet reasonableness' of the Greek mind gradually dissipated the animistic fog, a few words must be said about the history of the Greeks. Without that amount of history it would seem a miracle that Man ever became reasonable at all.

The Medicine we call Greek might be described as the system which prevailed in ancient times in that half of the Mediterranean area which lies east and south of the Italian Peninsula.

Up to about 1000 B.C. most of the coast-lands of this Mediterranean area were inhabited by that very remarkable people, the Minoans. These have left some extraordinary remains, the full significance of which has not yet been revealed. The general development of the Minoan civilization has, however, been clearly outlined by modern archaeological investigation. This has resulted in an entirely new interpretation of the story which Homer tells in the *Iliad*. The siege of Troy represents an attack by the invading Greeks on one of the last Minoan strongholds. About 1000 B.C. the whole Eastern Mediterranean basin was being overrun by the Greek tribes coming in from the north. These Greeks were no pure race, but a mixed multitude of invaders who came along several lines of advance. As always

happens in such invasions, the conquered were not exterminated, but mingled with the invaders. Thus the Greeks, as they advanced, absorbed much of the culture and outlook of the civilization that they submerged.

In considering the history of Rational Medicine we are concerned chiefly with two main invading streams of Greek tribes: that of the Dorians, who passed towards Crete and towards the Island of Cos and the opposite peninsula of Cnidus, and that of the Ionians, who colonized most of the remaining part of western Asia Minor. These two peoples were, between them, responsible for the main intellectual output of the Greeks of those early days. The medical system which they initiated first took shape in western Asia Minor, and thence became diffused over the whole of the Greek world. The Greek system of Medicine which thus arose in Asia Minor had various roots, as indeed the Medicine of a mixed people, living under very complex social conditions, was bound to have.

Firstly, there was the submerged civilization of the conquered Minoan folk. It is probable that the cult of the serpent—so constantly associated with Aesculapius and still used as a medical emblem—was of Minoan origin, for the serpent was a symbol much used in the Minoan religion (Fig. 2). It is probable too that some of the hygienic ideas of the Greeks were derived from the same source, for the Minoans had an excellent system of drainage. We can, however, say little on this head because the interpretation of the Minoan records is still hidden from us.

Secondly, we have to remember that the shores of Asia Minor lie on the outskirts of the great civiliza-

tion which had grown up in the valley of the Tigris and the Euphrates. The Greeks drew from that source

FIG. 2

FIG. 3

FIG. 2. IVORY AND GOLD MINOAN STATUETTE of a votaress in a state of ecstasy. In either hand she holds a serpent, illustrating the importance attached to this animal in the Minoan cult. From the Museum of Fine Arts, Boston, U.S.A.

FIG. 3. SURGICAL INSTRUMENTS recovered from Babylonian sites. There are here represented two knives, a saw, and a chisel or raspara-tory. These instruments, which illustrate the state of surgery in the ancient Mesopotamian civilization, are in the possession of Professor Meyer-Steineg of Jena, by whose permission they are here reproduced.

much of their more superstitious beliefs, as well as some, at least, of their scientific method. On the one hand, the demoniac theories that bulk so largely in

later Greek medicine doubtless came from Assyria and Babylonia. The Medicine of the New Testament, for instance, with its casting out of devils, is of Mesopotamian origin. But, on the other hand, the Mesopotamian peoples had for long ages laid up a great

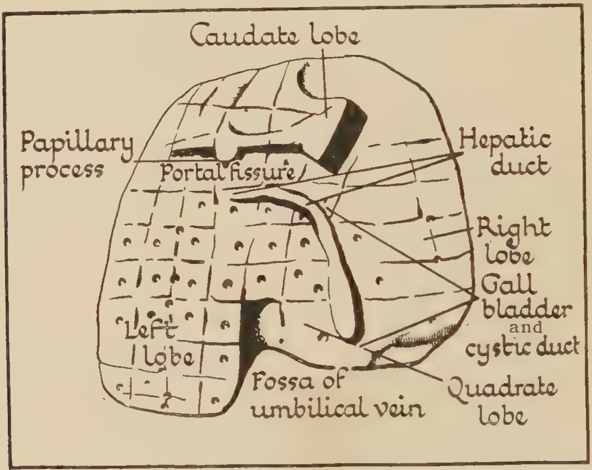


FIG. 4. CLAY MODEL OF SHEEP'S LIVER used for instruction in divination in a Babylonian temple school. The object is now in the British Museum. It is covered with cuneiform writing, the nature and contents of which fix its date as about 2000 B.C. The writing is here omitted for the sake of simplicity.

Various parts of the liver have their Babylonian technical terms and can be identified with parts recognized by modern anatomists. Some of these modern terms are written on our drawing.

To each hole in the original model an inscription containing a forecast is assigned. The diviner made his forecast by comparing an actual liver with this clay model at each point corresponding to a hole. His forecast was elaborated according to the state of the liver at all these points.

treasury of observation, notably of astronomical data which were often applied to astrological ends. There was also some knowledge of anatomy derived from the entrails of animals used in divination (Fig. 4). Working

on the basis of these records, the Greeks were able to erect a scientific method which appears as a prominent feature in their intellectual life in later centuries. Moreover, there was in Mesopotamia a standardization of both medical and surgical procedure which the nimble-witted Greeks were quick to adopt (Fig. 3). On its lower and less intelligent side, however, the Mesopotamian material was made to minister to Greek superstition and especially to astrological belief.

Thirdly, to the Egyptian civilization the Greek debt was also considerable. Many drugs were derived from Egypt and others were suggested by Egyptian practice. The basis of Greek medical ethics, too, can be traced to Egypt. Some of the practical devices of Greek Medicine, such as the forms of the surgical instruments, were of Egyptian origin. Nor can we neglect the statement made by the Greeks themselves, that mathematical knowledge—the test and index of all scientific growth—came to them first from Egypt. Lastly, we note that the Egyptians deified a physician, Imhotep (Fig. 5), in exactly the way that the Greeks deified their physician Aesculapius (Fig. 6). Both Imhotep and Aesculapius were, in fact, historic personages, and their evolution into gods presents many interesting parallels.

The Greeks of western Asia Minor, thus drawing material from many sources, came to develop, towards the end of the seventh century B. C., a philosophical system from which the whole of their Science may be said to be a natural growth. Factors in this development were the medical schools of Cos, where Hippocrates was born, and of the opposite peninsula, Cnidus. These schools were in active operation by the sixth

century B. C. By the middle of the fifth century they were important elements in the growing complexity of Greek life. Much of the so-called *Hippocratic Collection*, which contains the earliest Greek medical writings that

FIG. 5

FIG. 6

FIG. 5. IMHOTEP, originally a physician, subsequently deified as an Egyptian god of Medicine. From a statuette in the British Museum.

FIG. 6. AESCULAPIUS, originally a physician, subsequently deified as a Greek god of Medicine. He holds a staff, around which a serpent twines. From a statue in the Capitoline Museum at Rome.

have survived, must have been put together somewhere in the fourth century B. C., though its final recension is certainly later (Fig. 7). In that final recension Persian and Indian elements were also included, though to what degree is still very uncertain.

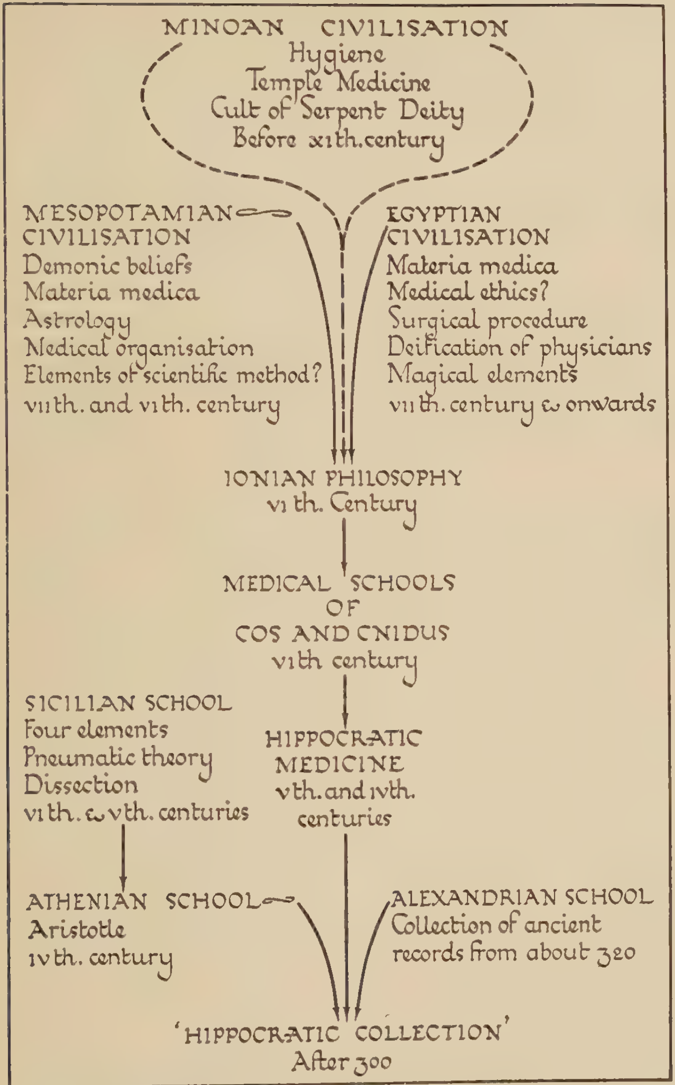


FIG. 7. SCHEME ILLUSTRATING SOME OF THE SOURCES OF HIPPOCRATIC MEDICINE

But the picture of the development of Greek Medicine is not yet complete. Although we inherit the scientific spirit from the Greeks, and although they set a standard for all time of the purest and most disinterested type of medical practice, they are also in part responsible for some of the basest forms of medical jugglery that have afflicted and still afflict mankind. The medicine of the physicians was only one of their medical systems. There was a far lower form which gradually passed into the hands of the priests. The temple jugglery of Greece is ancestor, both by imitation and by direct tradition, of much medieval and modern medical miracle-mongering.

Furthermore, in ancient as in modern times, all medical men were not equally pure in aim or scientific in method. The practice of some Greek physicians was more than flavoured with magic. In justice, also, it must be said that not all priests were mere charlatans, and that there are traces of scientific method in the treatment of patients in the temples. There was, indeed, a relation between the practice of some of the physicians among the Greeks and that of some of their priestly magicians. We shall not attempt to determine the actual extent and nature of this relationship. For our purpose it is enough that the two systems were quite distinct in their most typical developments.

The temple system of Greek Medicine was associated from an early date with a deity, Asklepios, or, to give him his better-known Latin name, Aesculapius. Numerous representations of him have come down to us, and in them we see him gradually moulded to a particular type. He becomes at last an aged man of noble,

benevolent and dreamy aspect, holding in his hand a staff around which a serpent twines (Fig. 6). The cult of the god Aesculapius was carried on at numerous sites. The best known, both from literature and excavation, is Epidaurus. The conditions there are typical of those in other Aesculapian centres.

Epidaurus is about thirty miles from Athens. It lies between two considerable ranges of hills, and the country bears still, in its customs and place-names, some remnants of the ancient cult. One tradition tells that a certain maiden, Koronis, being with child by Apollo, brought forth the infant Aesculapius on the mountain above Epidaurus. There is still a village named Koroni hard by. She fled to conceal her shame and left the child on the mountain, where it was tended by a goat and watched over by a dog. The infant performed various miracles which we need not pursue, though the temple arose on the site where he is said to have wrought them. One of his miracles, however, has a wider interest and is worth recounting. A certain Hippolytus, falsely accused of impure relations with his stepmother, was slain by the gods in answer to the curses of his father, Theseus. Raised from the dead by the wonder-working Aesculapius, he reappears in legend at the Arician grove in Italy. 'There', says a Greek chronicler of the second century A. D., 'he became a king and devoted a precinct to Artemis, where, down to my time, the prize for the victor in single combat was the priesthood of the goddess. The contest was open to no freeman, but only to runaway slaves.'

The son slain by his father and then rising from the dead; the runaway slave seeking sanctuary with Artemis

in her grove, allowed his liberty and elevated to the priesthood there; the priesthood held only so long as the priest can guard it in mortal combat against the next runaway slave; this succession of slave kings and priestly murders has touched the imagination of the poets and artists in ancient and in modern times. The sacred grove of Artemis stood by the side of the lake of Nemi:

> The still glassy lake that sleeps
> Beneath Aricia's trees—
> Those trees in whose dim shadow
> The ghastly priest doth reign,
> The priest who slew the slayer
> And shall himself be slain.

It is a picture utterly out of accord with the general trend of classical mythology. Long ago scholars saw therein a remnant of a submerged faith, that ancient 'Nature worship' which survived among the Greeks, and survives with us. From this incident is named the great classical work of Anthropology, *The Golden Bough*. By this story and by all that it implies, by all that learning has drawn out of it and associated with it, the history of Medicine comes into contact with the brooding spirit of savage man. Into that dark realm we shall not enter in this volume.

History is the tale of the spirit of Man unfolding itself. This process is always slow, often imperceptible, sometimes retrograde, yet over long periods of time it is sure. Where no evolution of the spirit can be traced true history cannot be written, wherefore no man can write a history of human folly. Irrational man, driven by disease and fear of death, exhibits the same follies

in all ages. The medical follies and superstitions of our own days are as in those when Aesculapius claimed men's allegiance. His garments and his names are changed, his temples are transformed, his priests assume other titles, but his face is the same, and he works the same wonders with about the same frequency. It is of Rational Medicine that we have henceforth to speak.

§ 2. *The Hippocratic Physician.*

We turn to the other side of the picture. Nothing could be in greater contrast to the orgies of the savage, the dark ways of the magician, or the charlatanry of the priests, than the serene spirit of wisdom which pervades the best Greek Medicine. The finest presentation of that system is to be found in a group of about a hundred works that have been associated together since antiquity under the name of Hippocrates. It is known as the *Hippocratic Collection.*

It will naturally be asked, 'Which of these works is by the man whose name they bear?' To that question, alas, no definite answer can be given. There is no single work which we can state with certainty to be the composition of the Father of Medicine. The books of which the *Collection* is composed are the work of a number of authors, belonging to different schools, holding various and often contradictory views, living in widely separated parts of the Greek world and writing at dates divided from each other, in the most extreme cases, by perhaps five or six centuries. Of the finest books of this collection we can but say that they contain nothing inconsistent with a Hippocratic origin, that their ethical standpoint is in accord with the Hippocratic

ideal, and that they are the work of physicians of great intellectual power and experience.

If we ask what is known about Hippocrates himself, and if we seek information rather than entertainment, our answer will be almost as meagre. Hippocrates is no mythical figure, for he is mentioned with high respect by his younger contemporary, Plato. He was the son of a physician, and was born at Cos about 460 B.C. The most active period of his life thus began about 420 B.C. His death is placed between 377 and 359—the latter would make him 101, an appropriate age for a great physician. He led a wandering life, and is heard of at Cos, Thasos, Athens, in Thrace and elsewhere, and lastly in Thessaly, where his grave was long shown. Among his pupils were his two sons, and his son-in-law. Of the work of the latter we have a fragment preserved both by Aristotle and in the *Hippocratic Collection* itself.

That is all that is known about the Father of Medicine. We have not even his portrait. Yet we have something far better; we have an idealized representation of what the Greek would wish his physician to be. It is a noble bust to which the name of Hippocrates was early attached. Many copies exist (see Frontispiece). The calm, righteous and dignified presence which it portrays has stamped itself on the consciousness and conscience of those who follow the Art of Healing. To that gracious figure the medical man will continue to pay homage.

If critical examination has dealt thus hardly with the Hippocratic writings and with Hippocrates himself, what has been left which we may surely derive from the

Greek medical system? The answer is that Medicine has from the Greeks two great things: the picture of a man and the institution of a method.

The man is Hippocrates himself. His figure, gaining in dignity what it loses in clearness, stands for all time as that of the ideal physician, for the ideal is there and is clearly set forth in these great writings, whether we discern the details of his earthly features or no. Calm and effective, humane and observant, prompt and cautious, at once learned and willing to learn, eager alike to get and give knowledge, unmoved save by the fear lest his knowledge may fail to benefit others—both the sick and their servants the physicians,—incorruptible and pure in mind and body, the figure of the greatest of physicians has gained, not lost, by time. In all ages he has been held by medical men in a reverence comparable only to that which has been felt towards the founders of the great religions by their followers. The figure of the Hippocratic physician has been of incalculable spiritual value to the medical profession in the twenty-three centuries that have passed since his death.

So much for the man. We turn now to the method.

The *method* of Hippocratic medicine is that known to-day as the *experimental* or better *experiential*. It was employed among the Greeks for centuries after the death of Hippocrates. Then came a time when a social and philosophical upheaval prevented its further prosecution. For the thousand years that followed the break-up of the Roman Empire the medical practice of Europe was at best a corrupted imitation and misunderstanding of the Hippocratic teaching; at worst it descended to a

low level of Animism and Magic. Then there was a rally. Slowly—very slowly at first—the foundations of Modern Science were laboriously laid. Among the first elements in this scientific Renaissance was the recovery of the Hippocratic works.

In the centuries that followed this Renaissance the very words of the *Hippocratic Collection* were taught in the medical schools in a spirit that was anything but that of Hippocrates. Gradually, however, a better understanding crept into men's minds. The spirit of those writings and their methods and observations came now rightly to be exalted above the works themselves. The works themselves were wisely dropped from the medical curriculum. They are no longer used in any medical school. But if we turn again to contemplate the Hippocratic treatises, we may recognize in them the modern process of careful record of data and cautious inference from them—that collation of experience from various sources obtained by various methods with which we are now so familiar. We may even see in full force the actual process of case-taking, bedside instruction and clinical lecture. These methods are practised much in the way in which we know them, and are set forth with a conciseness and beauty of language and a loftiness of ethical tone which have not since been surpassed. To such a collection medical men must always return. No part of it is more impressive than the so-called *Hippocratic Oath*.

The *Hippocratic Oath*, in its present form, is of very much later date than Hippocrates. Yet parts of it may be even earlier than he, and some suggestion of the Oath is, perhaps, to be seen in the contents of

Egyptian papyri of the second millennium B.C. It need hardly be said that the late date of the *Oath* by no means removes the interest of this grand ethical monument. No passage better reflects the spirit of the

FIG. 8. A GREEK CLINIC OF ABOUT 400 B.C., when Hippocrates was in his prime. From a vase painting.

The physician sits in the centre. He holds a lancet in his right hand, seizes the patient's right arm with his left and is bleeding him from a vein at the bend of the elbow. The blood falls into a large basin on the floor. Above the physician's head are suspended three cupping vessels, shaped thus: 

To the right sits a patient awaiting his turn to interview the physician. His left arm is bandaged. Behind this patient stands a figure smelling a flower as a preventive against infection. Behind the physician stands a man wounded in the left leg, which is bandaged. Back to back to this last figure is a dwarf with a disproportionately large head. His body exhibits deformities typical of the developmental disease now known as *Achondroplasia*. In addition to his other deformities, we note that his muscular body is hairy, and that the bridge of his nose is sunken. On his back he carries a hare which is almost as tall as himself. Talking to the dwarf is a man leaning on a long staff, who has the remains of a bandage round his chest.

Hippocratic physicians. The oath is clearly designed for a youth entering on his apprenticeship to such a one.

'I swear by Apollo the healer, invoking all the gods and goddesses to be my witnesses, that I will fulfil this Oath and this written Covenant to the best of my ability and judgement.

'I will look upon him who shall have taught me this Art even as one of my own parents. I will share my substance with him, and I will supply his necessities, if he be in need. I will regard

his offspring even as my own brethren, and I will teach them this Art, if they would learn it, without fee or covenant. I will impart this Art by precept, by lecture and by every mode of teaching, not only to my own sons but to the sons of him who has taught me, and to disciples bound by covenant and oath, according to the Law of Medicine.

'The regimen I adopt shall be for the benefit of the patients according to my ability and judgement, and not for their hurt or for any wrong. I will give no deadly drug to any, though it be asked of me, nor will I counsel such, and especially I will not aid a woman to procure abortion. Whatsoever house I enter, there will I go for the benefit of the sick, refraining from all wrongdoing or corruption, and especially from any act of seduction, of male or female, of bond or free. Whatsoever things I see or hear concerning the life of men, in my attendance on the sick or even apart therefrom, which ought not to be noised abroad, I will keep silence thereon, counting such things to be as sacred secrets. Pure and holy will I keep my Life and my Art.

'If I fulfil this Oath and confound it not, be it mine to enjoy Life and Art alike, with good repute among all men at all times. If I transgress and violate my oath, may the reverse be my lot.'

§ 3. *Hippocratic Practice.*

Among the most remarkable features of the *Hippocratic Collection* is the feeling of contact with the patient which most of its works convey. This is naturally a special characteristic of the surgical works. One treatise, which bears the title *On wounds of the head*, has always drawn attention as bespeaking especial ingenuity and experience. The description of trephining is of peculiar interest, because the practice was known in prehistoric times and is still employed by savage and semicivilized peoples. The process recommended for cases of fracture of the skull and injury to the underlying structures

resembles, in many details, the modern surgical procedure.

'When it is necessary to trephine a patient, make up your mind and judge as follows. If you have had charge of the case from the first, do not trephine the bone down to the membrane at once, for it is not desirable that the membrane be long exposed, lest it end by becoming rotten and fungous. There is also another danger, to wit that you wound the membrane with the saw during the operation, if you try to remove the bone by trephining immediately down to the membrane. Therefore, when the bone is almost sawn through and is already loose, cease trephining and allow the bone to come away of itself. While trephining, often remove the instrument and dip it in cold water. If you do not do this, the trephine, becoming heated by the circular motion and heating and drying the bone, may burn it and cause an unduly large piece of the bone round the sawing to come away.'

So much for a normal case which comes to the physician's hands directly after the accident. But in less fortunate cases he is not called in so early, and the wound suppurates before he can bring his Art to bear upon it. In such a case he is advised:

'Saw the bone immediately to the membrane with a serrated trephine (Fig. 9, *a* and *c*), frequently removing the trephine and testing with the probe all round along the track, for the bone is sawn through much more quickly if it is already suppurating and penetrated by the pus. The bone, however, often happens to be thin in places. Therefore be on your guard not to apply the trephine at random, but fix it in the bone where it appears thickest, frequently making an examination and trying to raise the bone by moving it. And after removing it, continue such treatment as may appear advantageous to the wound, according to circumstances.'

Among the works of the *Hippocratic Collection* is a lecture note-book known by the title *Concerning the*

things in the Surgery. It is written in very abbreviated style and consists of mere headings. Nevertheless, our

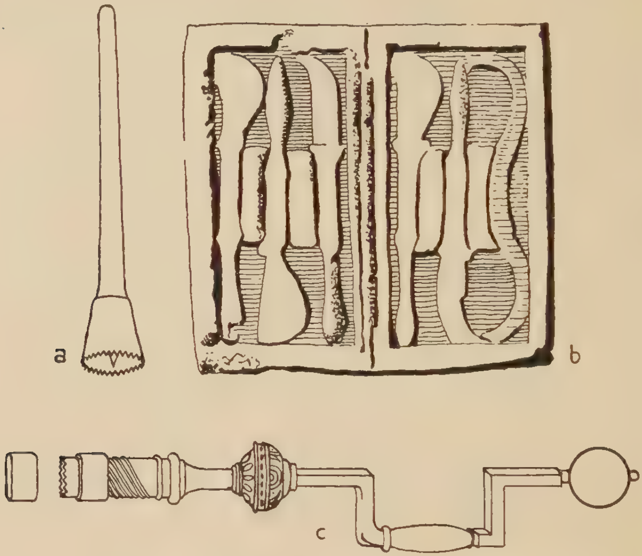


FIG. 9. INSTRUMENTS USED BY GREEK SURGEONS.

a Simplest form of trephine. It has central pin and serrated edge. The point is held against the skull and the staff twirled between the hands. (Cf. Fig. 112.) It could also be rotated by a crosspiece and thong, as in Fig. 22. *b* Case of scalpels from a bas-relief in the temple of Aesculapius on the Acropolis at Athens. *c* Trephining instrument of type still in use. The carpenter's 'centre bit' was known in antiquity, and was probably adapted to the trephine. *a* and *c* represent sixteenth-century instruments of ancient type. No ancient trephines are known, though descriptions of their use have survived.

attention is arrested by its startling modernness, when we read such a category as this:

'Operative requisites in the surgery: the patient; the operator; assistants; instruments; the light, where and how placed; the

patient's person and apparatus. The operator, whether seated or standing, should be placed conveniently to the part being operated upon and to the light. Each of the two kinds of light, ordinary or artificial, may be used in two ways, direct or oblique.'

Or again, such details as:

'The nails [of the operator] neither to exceed nor come short of the finger-tips. Practise using the finger-ends. Practise all operations with each hand and with both together, your object being to attain ability, speed, painlessness, elegance and readiness. Let those who look after the patient present the part for operation as you want it, and hold fast the rest of the body so as to be all steady, keeping silence and obeying their superior.'

Are we not here reminded of an up-to-date operator and operating theatre?

In the *Hippocratic Collection* the physician attends cases of every type, and does not refuse to do his best for a case because the use of an instrument is demanded. He is thus no 'specialist'. But the mass of his practice lay with cases to which instrumental treatment was inapplicable. In cases in which surgical intervention was not justified the Hippocratic physician adopted for the most part what is called an 'expectant' line of treatment. Realizing that, in general, the tendency of the body is to recover, he contented himself with 'waiting on Nature'. This does not by any means imply that he was helpless, for much could be done by nursing, regimen and diet to aid the patient in that conflict which he alone must fight out. For the conduct of that great battle wise and useful directions are recorded. But believing in *the healing power of Nature*—the famous phrase is used in the Hippocratic writings—the physician was none too eager to administer drugs. In the state of knowledge of

the day this reluctance was well-judged. Nevertheless the Hippocratic drugs, though neither numerous nor complex, were some of them very efficient, and their judicious if reluctant use at the right juncture saved many a life.

The Aphorisms is the most famous book with which the name of Hippocrates is associated, and is as likely as any of the Collection to be by Hippocrates himself. It consists of a series of very brief generalizations. Many of these have been confirmed by the clinical experience of later ages. Some have passed into medical commonplaces, others have become popular proverbs. The style of the work suggests an aged physician reflecting on the experience of a lifetime. Among modern medical writings its closest analogue is perhaps the *Commentaries* of the great English physician, William Heberden the elder (1710–1801), which was commenced by him after the age of seventy, occupied the last twenty years of his life, contained a summary of the whole of his vast experience, and was published by his son after his death. If the *Aphorisms* is similarly a work of the old age of Hippocrates it may be dated about 380 B.C. A few extracts give a good idea of the nature of the book.

'Life is short and Art is long; the Crisis is fleeting, Experiment risky, Decision difficult. Not only must the physician be ready to do his duty, but the patient, the attendants, and external circumstances must conduce to the cure.'

'Old persons bear fasting most easily, next adults, and young people yet less; least of all children, and of these least again those who are particularly lively.'

'If in any illness sleep does harm, it is a symptom of deadly import.'

'When sleep puts an end to delirium, it is a good sign.'

'Weariness without cause indicates disease.'

'If there be a painful affection in any part of the body, and yet no suffering, there is mental disorder.'

'To eat heartily after a long illness without putting on flesh is a bad portent.'

'Food or drink slightly inferior in itself, but more pleasant, should be preferred to that better itself, but less pleasant.'

'The old have fewer illnesses than the young, but if any become chronic with them they generally carry it with them to the grave.'

'Those naturally very fat are more liable to sudden death than the thin.'

'The dry seasons are more healthy than the rainy, and attended by less mortality.'

'Cold sweats in conjunction with an acute fever indicate death, but with a milder fever only prolonged sickness.'

'Convulsions supervening on a wound are deadly.' (Tetanus, cp. p. 267.)

'Those attacked by tetanus either die within four days, or if they get through these they recover' (compare pp. 257 and 267).

'Phthisis comes on mostly from eighteen to thirty-five years of age.'

'It is fatal for a woman in pregnancy to be attacked by one of the acute diseases.'

'In cases of jaundice, hardening of the liver is a bad sign.'

'We should observe the appearance of the eyes in sleep. If any of the white show through the eyelids when closing, this is a bad sign and very dangerous, unless it be due to diarrhoea or taking a purgative.'

'An attack of delirium with laughter is less dangerous than with despondency.'

'Apoplexy is commonest between the ages of forty and sixty.'

'If you give the same nutriment to a patient in a fever and to a person in health, the patient's disease is aggravated by what adds strength to the healthy man.'

The chief clinical achievement of the *Hippocratic Collection* lies in the descriptions of actual cases. These

descriptions are not only without parallel during nearly 2,000 years, but they are models of what succinct clinical records should be. They are clear and short, they give all the leading features and yet they show no attempt to prejudge the importance of any particular feature. The records of these cases illustrate the Greek genius for seizing the essential. The writer does not betray the least wish to exalt his own skill. He seeks merely to put the data before the reader for his guidance under like circumstances. It is a reflex of the spirit of honesty in which these men worked that in the great majority of the cases they record death ensued. Two of these remarkable descriptions may be given:

'The woman with quinsy, who lodged with Aristion; her complaint began in the tongue; voice inarticulate; tongue red and parched. *First day*, shivered, then became heated. *Third day*, rigor, acute fever; reddish and hard swelling on both sides of neck and chest; extremities cold and livid; respiration elevated; drink returned by the nose; she could not swallow; alvine and urinary discharges suppressed. *Fourth day*, all symptoms exacerbated. *Fifth day*, died.'

This was a case of Diphtheria. The quinsy, the paralysis of the palate leading to return of the food through the nose, and the difficulty with speech and swallowing are typical results of this affection which was here complicated by a spread of the septic processes into the neck and chest, a not uncommon event in the disease. The rapid onset of the conditions is rather unusual, but may be explained if we regard the case as a mild and unnoticed diphtheria, subsequently complicated by paralysis and by secondary septic infection, for which reason she came under observation.

'In Thasos, the wife of Delearces, who lodged on the plain, through sorrow was seized with an acute and shivering fever. From first to last she always wrapped herself up in her bedclothes; kept silent, fumbled, picked, bored, and gathered hairs [from the clothes]; tears and again laughter; no sleep; bowels irritable but passed nothing; when urged drank a little; urine thin and scanty; to the touch the fever was slight; coldness of the extremities. *Ninth day*, talked much incoherently, and again sank into silence. *Fourteenth day*, breathing rare, large and spaced, and again hurried. *Seventeenth day*, after stimulation of the bowels she passed even drinks, nor could retain anything; totally insensible; skin parched and tense. *Twentieth day*, much talk, and again became composed, then voiceless; respiration hurried. *Twenty-first day*, died. Her respiration throughout was rare and large; she was totally insensible; always wrapped up in her bedclothes; throughout either much talk, or complete silence.'

We have here a description of low muttering delirium, a common end of continued fevers, as, for instance, Typhoid. It resembles the condition known to physicians as the 'typhoid state'. Incidentally the case contains a reference to a type of breathing common among the dying. The respiration becomes deep and slow, as it sinks gradually into quietude and becomes rarer and rarer until it seems to cease altogether, and then it slowly becomes more rapid and so on alternately. This type of breathing is known to physicians as 'Cheyne-Stokes' respiration, in commemoration of two distinguished Irish physicians of the last century who brought it to the attention of medical men. In our own time it has been partially explained on a physiological basis.

We may note that there is another and even better pen-picture of Cheyne-Stokes respiration in the *Hippocratic Collection*. We read of one 'Philescos who lived by the wall and who took to his bed on the first day of acute

fever'. About the middle of the sixth day he died, and the physician notes that 'the respiration throughout was *like that of a person recollecting himself* and was large and rare'. Cheyne-Stokes breathing is admirably described as 'that of a person recollecting himself'.

Immense and, as some may think, overwhelming importance is laid by the Hippocratic writings upon the art of 'Prognosis', that is of predicting the course which the disease will take. The work to which the title *Prognostics* is attached represents a very lofty standard of practice. We quote from it a description of the signs of death to which the name of *Hippocratic facies* has become attached. It is imitated by Shakespeare in his description of the death of Falstaff in Henry V (*Act II, Scene* 3).

'You should observe thus in acute diseases; first the countenance of the patient, if it be like those of persons in health, and especially if it be like itself, for this is best of all. But the opposite are the worst, such as these: a sharp nose, hollow eyes, collapsed temples; the ears cold, contracted, and their lobes turned out; the skin about the forehead rough, stretched and parched; the colour of the face greenish, dusky, livid or leaden.

'If the countenance be such at the beginning of the disease, and if this cannot be accounted for by the symptoms, inquiry must be made whether the patient has been sleepless, whether his bowels have been very loose, or whether he has wanted food. If any of these be confessed, the danger is to be reckoned so far the less, and it will become obvious in a day and night whether or no the appearance come of these. But if no such cause exist and if the symptoms do not subside in this time, be it known for certain that the end is at hand.'

These glimpses will give some idea of Rational Medicine in the making. In the fourth century B.C. Medicine emerges as a definite part of the scientific consciousness. Rational Medicine is now in being.

§ 4. *Aristotle.*

During the fourth century B. C. there lived and worked one whose thought has stamped itself on the whole subsequent course of the biological and medical sciences, and indeed of all Science.

Aristotle (384–322 B.C.) was a provincial Greek and son of a Macedonian physician. At seventeen he became a pupil of Plato at Athens. After Plato's death in 347 Aristotle crossed the Aegean to reside in Asia Minor. The main part of his biological observations was made during his stay there. In 342 B.C., at the request of King Philip of Macedon, Aristotle became tutor to Philip's son, Alexander the Great. He remained in Macedon for seven years. About 336, when Alexander departed for the invasion of Asia, Aristotle returned to Athens, where he taught for the rest of his life. He died in 322 B.C., a few months after his pupil Alexander.

Aristotle was the great codifier of ancient Science. On him all subsequent biological development, including that of modern times, is surely based. In his wonderful biological works, which are still read by naturalists, he discusses many problems current to this very day. He laid the basis of the doctrine of Organic Evolution in his teaching concerning the *Scala Naturae* 'Ladder of Nature' (Fig. 10). He developed coherent theories of Generation and Heredity. He founded Comparative Anatomy and he dissected many animals. He did not, however, anatomize the human body.

Aristotle gave good descriptions of some organs, regarded from the standpoint of Comparative Anatomy. These descriptions he sometimes illustrated by draw-

ings, the first anatomical figures of which we have a record. In some cases these drawings can be restored with confidence. Thus, he gave an account of the uterus, the nomenclature of which has been retained in more or less modified form to our own time (Fig. 11). Among

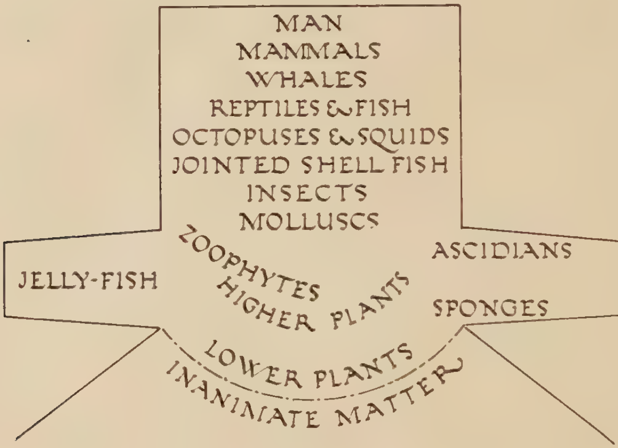
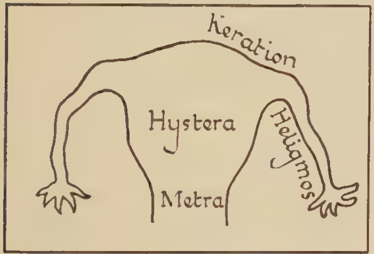


FIG. 10. The *Ladder of Nature* according to Aristotle.

the best anatomical descriptions given by Aristotle is that of the ruminant stomach. Perhaps his most extraordinary anatomical feat is his account of the development of the dog-fish *Mustelus laevis*, which he showed was attached to its mother's womb in a way very similar to the embryo of a mammal (Fig. 12). This raised the admiration of the greatest modern morphologist, Johannes Müller (1807–58, pp. 211–13), and would in itself be sufficient to establish the claim of Aristotle to a place in the front rank of observing naturalists. Aristotle gave fairly accurate descriptions of the branches of the great

veins and of the superficial vessels of the arm of mammals. He realized that the arteries are usually accompanied by veins. He described the generative and digestive organs of cephalopod Molluscs, and many other parts of many other animals.

Something should be said of the errors of Aristotle. Though an excellent Naturalist, he was in general much



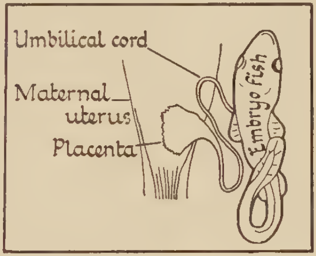


FIG. 11. The womb with the names of its parts as given by Aristotle. These names remain, in various forms, in modern anatomy.

FIG. 12. Embryo dogfish, *Mustelus laevis*, after Johannes Müller. The little creature is shown attached to the wall of its mother's womb, somewhat after the manner of a mammal.

weaker in Physiology. Thus, he made no proper distinction between arteries and veins. He failed to trace any adequate relations between the sense organs, the nerves, and the brain. His refusal to attach great importance to the brain is remarkable. Primacy he placed with the heart, which he regarded also as the seat of the intelligence. This was contrary not only to the medical opinion of his day, but also to the popular view, voiced, for instance, by Aristophanes in his play *The Clouds*, written about 400 B.C., where we read of a man who had *concussion of the brain*. Moreover, Aristotle's teacher Plato placed the seat of thought and feeling in the

brain. From all we know of Aristotle, it seems probable that he did not take up this attitude without evidence. It seems likely that he had experimented on the brain and found it devoid of sensation. Hence his view, opposed to current belief, that it is not associated with thought. Aristotle regarded the brain simply as an agent for cooling the heart, and preventing it from being over-heated. This cooling process, he considered, was effected by the secretion of *phlegm* (*pituita*), an idea still preserved in our anatomical term the *pituitary body*.

The views of Aristotle have had a vast influence in determining the direction of medical thought. For more than two thousand years Aristotelian philosophy, in more or less corrupted form, constituted the main intellectual food of mankind. Without some knowledge of the biological verdicts of Aristotle, it is impossible to understand the course taken by Rational Medicine. The influence of Aristotle is specially evident in certain basic biological conceptions.

The problem of the nature of Generation is one in which Aristotle never ceased to take an interest. Among the methods by which he sought to solve it was embryological investigation. His most important embryological researches were made upon the chick. His choice was most fortunate, and the chick has remained, to this day, the classical subject of embryological research. Aristotle asserts that the first signs of life in the hen's egg are noticeable on the third day, the heart being visible as a palpitating blood-spot. As it develops, two meandering blood-vessels extend to the surrounding tunics. A little later, he observes, the body becomes

distinguishable, at first very small and white, the head being clearly distinguished and the eyes very large (Figs. 46–7, p. 117). To follow the main features of the later stages was a comparatively easy task.

Aristotle was greatly impressed by these phenomena. He lays stress on the early appearance of the heart in the embryo. Corresponding to the general gradational view that he had formed of Nature, he held that the most primitive and fundamentally important organs make their appearance before the others. Among the organs all give place to the heart, which he considered the first to live and the last to die. In the heart, as we have seen, he placed the seat of the intelligence.

Thus, not only in his account of the 'Ladder of Nature', but also in his theories of individual development, Aristotle exhibits some approach to evolutionary doctrine. This is somewhat obscured, however, by his peculiar view of the nature of procreation. On this topic his general conclusion is that the material substance of the embryo is contributed by the female, but that this is mere passive formable material, almost as though it were the soil in which the embryo grows. The male, by giving the principle of life, the *soul* (*psyche*), contributes the essential generative agency. But this *soul* is not material, and it is not, therefore, theoretically necessary for anything material to pass from male to female. The material which does in fact pass with the semen of the male is, as the older philosophers would have said, an *accident*, not an *essential*. The essential contribution of the male is not matter but *form* and *principle*.

The female then only provides the *material*, the male

the *soul*, the form, the principle, that which makes life. Aristotle was thus prepared to accept instances of fertilization without material contact, i.e., in effect, *parthenogenesis* or 'virgin birth'. In the centuries that came after him such instances were not infrequently adduced, and this doctrine was given a special turn by Christian theologians. Belief in the 'accidental' character of the material contribution of the male was common among men of science till the nineteenth century. The general attitude as to the nature of fertilization set forth, for instance, by William Harvey (1578–1657, pp. 111–14) in his book, *On the Generation of Animals*, published in London in A.D. 1651, is practically identical with the views of Aristotle published in Athens about 350 B.C., just 2,000 years earlier. It is of great interest to note that very recent embryological research goes some way to confirm this view of Aristotle. Without any intervention of the male sexual element, it is possible so to stimulate the egg mechanically as to produce a perfect animal which is thus fatherless from the first. The male element is indeed unnecessary and, in fact, transmits only hereditary characters.

We must say something concerning Aristotle's conceptions of the nature of Life itself. He was before all things a 'vitalist'. For him the distinction between living and not-living substance is to be sought not in material constitution, but in the presence or absence of something that he calls *psyche*, which we may translate 'Soul'. His teaching on this topic had the profoundest influence on subsequent anatomical and physiological thought.

Aristotle's theory as to the relation of this Soul to

material things is a difficult and complicated subject. Its adequate discussion would take us beyond our theme. He holds, however, that the Soul is related to the idea of *form*. In living things the soul is that which gives form. It is the pervasion by the soul that leads to the determinate development of the body and its parts. This activity of the Soul, under the Aristotelian term *Entelechy* (which we may perhaps translate 'the indwelling perfectability' or 'purposiveness', see *Preface*), has an important place in modern biological theory, which has, indeed, swung definitely in the direction of the Aristotelian position.

Aristotle defines Life, existing in Matter, as 'the power of self-nourishment and of independent growth and decay'. Of the Soul, the principle of Life, he distinguishes three orders or types, the lowest *vegetative*, or nutritive and reproductive, next the *animal* or sensitive, and highest the *rational* or intellectual soul. The last, he at first held, was peculiar to man, but later he modified this view.

The history of the reception of Aristotle's science by later ages is very strange to modern eyes. Of all Aristotle's scientific teachings, men clung most firmly for many centuries not to his finely thought-out biological conceptions, but to a doctrine of the constitution of matter of which the modern student hears nothing. Aristotle, following more ancient writers, held that there were four primary and opposite fundamental *Qualities*, the *hot* and the *cold*, the *wet* and the *dry*. These met in binary combination to constitute the four Essences or Existences which entered in varying proportions into the constitution of all Matter. The

four Essences, or, to give them their usual name, *Elements*, were *earth*, *air*, *fire*, and *water*. Thus, water was wet and cold, fire hot and dry, and so forth. With this theory later writers combined the somewhat similar Hippocratic doctrine which held that the body was composed of the four 'Humors' or liquids: *blood*, *phlegm*,

FIG. 13. The four *Elements* in association with the four *Humors* and the four *Qualities*.

black bile (melancholy), and *yellow bile* (choler). Some of the Hippocratic physicians had associated excess of the Humors with various types of bodily constitution. Their followers made much of the 'temperaments' resulting therefrom, and according to the prevailing humor they distinguished the sanguine, phlegmatic, melancholy or choleric temperament (Fig. 34, p. 97).

These conceptions, now departed altogether from our scientific discipline, still persist embedded in our language. Poetry still uses such ideas as the 'raging of

the elements' and 'elemental forces'. We may yet speak of a 'fiery nature' or an 'aerial spirit'. We know what is meant by a *sanguine* or a *phlegmatic* temperament, and a *melancholy* or *choleric* disposition, and such words conjure up real pictures in our minds (Fig. 34). Until it began to be undermined by Robert Boyle (1627–91) and others in the seventeenth century, the doctrine of the four elements persisted in its entirety, while ideas and terms derived from the old humoral pathology can, in fact, be traced in the medicine of the twentieth century.

The biological activity of the school of Aristotle was continued after his death by his pupil Theophrastus (372–287 B.C.). Especially the writings on plants of Theophrastus are instinct with a thoroughly scientific spirit, and are rightly regarded as the basic documents of the science of Botany. Nevertheless, his works had little effect or influence on his contemporaries and successors. With Theophrastus the purely biological school of Aristotle may be said to come to an end. The biological sciences ceased, for many centuries, to be studied for their own sake and became mere handmaidens of Medicine. Neither mistress nor servant was the better for the change.

II

THE HEIRS OF GREECE

(300 B.C. TO A.D. 200).

§ 1. *The Alexandrian School.*

SOON after Aristotle, about 300 B.C., a great medical school was founded at Alexandria in Egypt. That country had been conquered by Alexander the Great, after whom the town was named. On Alexander's death, Egypt came under the rule of one of his generals, Ptolemy, who established a dynasty which became extinct with the famous Queen Cleopatra, thirty years before the Christian era. Alexandria was a favourite residence of this Greek dynasty and became more Greek than Egyptian. Ptolemy and his successors were patrons of learning, and at the Alexandrian school remarkable anatomical and physiological researches were made. These were the work of Greek physicians who, in the tradition of their people, were only too wont to associate their discoveries with sweeping theoretical generalizations, often on very inadequate bases.

The two earliest medical teachers at Alexandria were also the greatest, Herophilus of Chalcedon, who flourished about 300 B.C., and his slightly younger contemporary Erasistratus of Chios. Herophilus may be regarded as the father of Anatomy, Erasistratus as the father of Physiology.

Herophilus was probably the first to dissect the human body in public. He recognized the brain as the

central organ of the nervous system and regarded it as the seat of the intelligence, thus reversing the verdict of Aristotle on the primacy of the heart. He was the first to grasp the nature of the nerves, which he distinguished as connected with motion and sensation (Fig. 98), though he did not separate them clearly from tendons and sinews. He greatly extended the knowledge of the parts of the brain. Certain parts of the brain still bear titles which are translations of those which he gave them. He also made the first clear distinction between arteries and veins.

At the time of the institution of the Alexandrian medical school, and for long after, there flourished that view of the structure of the world known as *atomic*, propounded by the philosopher Democritus (*c.* 400 B.C.). The chief exponent of the theory was Epicurus (342–270), whose philosophy was of the order which we should now call 'materialistic'. For it the only ultimate realities were atoms and 'the void', and everything was ultimately expressible in these terms. Epicurean philosophy was not without its reactions on Medicine at Alexandria, where its leading exponent was Erasistratus of Chios.

Erasistratus was essentially a rationalist and professed himself a foe to all mysticism. In the last resort, however, he had to invoke the idea of Nature as a great artist acting as an external power, shaping the body according to the ends to which it must act. This is in contrast with Aristotle's view of the 'soul' as an *Entelechy* (p. 33), an innate and inherent factor. Erasistratus sought to express his views in atomic terms, but, to make physiology intelligible, he added a concep-

tion, *Pneumatism*, found also among older thinkers. Pneumatism is the belief that the phenomena of life are associated with the existence of a subtle vapour, 'pneuma' or spirit, which permeates the organism, and causes its movements. This subtle vapour is held to have some affinities with the air we breathe. Pneumatism is, in fact, a primitive attempt to explain the phenomena of respiration.

Erasistratus observed that every organ is equipped with a threefold system of 'vessels', vein, artery, and nerve, which divide to the very limits of vision, and he considered that the process of division continues beyond those limits. The minute divisions of these vessels, plaited together, he believed to make up the tissues. Veins, arteries, and nerves are, for him, made of minute tubes of the same nature as themselves, through which they are nourished. Blood and two kinds of pneuma are the essential sources of nourishment and movement. The blood is carried by veins. Air, on the other hand, is taken in by the lungs and passes to the heart, where it becomes changed into a peculiar pneuma, the *Vital Spirit*, which is sent to the various parts of the body by the arteries. This spirit is carried to the brain, in the cavities or 'ventricles' of which it is further changed to a second kind of pneuma, the *Animal Spirit*. The animal spirit is conveyed to different parts of the body by the nerves, which are hollow.

In the brain Erasistratus observed the convolutions, noted that they were more elaborate in man than in animals, and associated this complexity with the higher intelligence of man. He distinguished between the main parts of the brain, the 'cerebrum' and 'cerebellum'

(Fig. 100, p. 210), and gave a detailed description of the 'cerebral ventricles' or cavities within the brain and of the 'meninges' or membranes that cover the brain. He considered that the cerebral ventricles were filled with *Animal Spirit.* (Compare Galen's scheme, p. 58.)

Erasistratus attained to a clear view of the action of muscles in producing movement. He regarded the shortening of muscles as due to distension by *Animal Spirit* conveyed to the muscles by the nerves. We may note that similar theories as to the nature of muscular action were again set forth, on theoretical grounds, in the seventeenth century by Descartes (1596–1650, pp. 127–8) and by Borelli (1608–79, pp. 129–30), but were rebutted by the experiments of Swammerdam (1637–80, p. 123). We may recall that we are still in the dark as to the mechanism of contraction of muscle fibre, the structure of which was first revealed by Leeuwenhoek (1632–1723, Figs. 55–56A, p. 121).

Erasistratus considered the chief cause of disease to be excess of blood or *Plethora*. Diseases thus caused differ according to their site. Among them are coughing of blood, epilepsy, pneumonia, tonsillitis, &c. Most of these diseases could be treated by diminishing the local supply of blood by starvation. Among his contemporaries and successors blood-letting was an habitual practice applied to almost every condition. Erasistratus employed it but rarely, and his followers banned it altogether. He was consistently opposed to violent remedies. Among the therapeutic measures which he favoured were regulated exercise, diet, and the vapour bath.

Erasistratus complained that many physicians of his

time were not interested in Hygiene. He therefore wrote a treatise on the subject. Though he regarded Hygiene as a means of substituting prevention for cure,

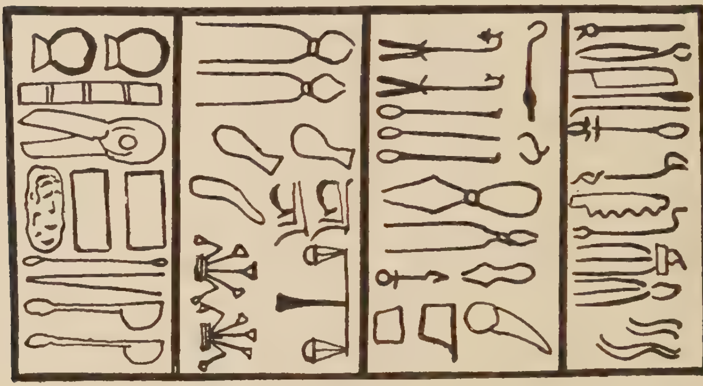


FIG. 14. INSCRIBED TABLET OF ABOUT 100 B.C. from the wall of the temple of Kom-Ombos in Upper Egypt. The temple itself was built by Ptolemy VII (181–146 B.C.), but the carving is later. It is divided into four partitions. These illustrate the surgical instruments in use in Egypt during Alexandrian times.

In the partition to the extreme left can be seen two cupping-glasses (cf. Fig. 8), a case of instruments (cf. Fig. 15), a pair of shears, a sponge, a probe, a pair of fine forceps, and two knives (cf. Fig. 9).

In the next partition to the right can be seen two large forceps, two bags or flasks, a strigil, two magic eyes, a pair of scales, and two growing plants.

In the next partition to the right can be seen several hooks of different forms, several knives, and two or three pairs of forceps.

In the partition to the extreme right can be seen a bifid probe, a pair of tongs, a long-bladed knife, probes, a double hook, a saw, a cautery, and several objects probably intended to represent bandages.

this did not prevent him from being extremely careful and precise in his treatment of cases.

After the first generation or two, the activity of the Alexandrian medical school flagged, though the city long remained a great teaching centre, and minor

medical advances were made. Surgery (cf. Fig. 14) seems to have languished less than Medicine. The stagnation in medical matters at Alexandria is in contrast to the continued activity there in Mathematics, Astronomy, Mechanics and Geography.

With the absorption of Egypt into the Roman Empire in 50 B.C. and the extinction of the Ptolemaic dynasty by the death of Cleopatra in 30 B.C., Alexandria ceased to have great scientific importance. The school continued for centuries with restricted activity and devoid of all originality. Intellectually, it had become subordinate to the Metropolis. Rome was now mistress of the world and the future of Medicine must be considered from the point of view of the Roman Empire.

§ 2. *Medical Teaching in the Roman Empire.*

The original native Roman medical system was quite devoid of scientific elements and was that of a people of the lower culture. Interwoven, as is all primitive Medicine, with ideas that trespass on the domains of religion and magic, it possessed that multitude of 'specialist deities' which was so characteristic of the Roman cults. The entire external aspect of Roman medicine was changed by the advent of Greek science. Yet, notwithstanding the large medical field that the Western Empire provided, and the wide acceptance of Greek medicine by the upper classes, it is remarkable that the Latin-speaking peoples produced no eminent physician.

At first scientific medical education at Rome was entirely a matter of private teaching. The earliest important scientific teacher there was the Greek Asclepiades of Bithynia (died *c.* 40 B.C.), a contemporary of

the poet Lucretius and, like him, an Epicurean. Asclepiades, like Erasistratus, imported the atomic view of Democritus into Medicine. He deeply influenced the course of later medical thought, ridiculed the Hippocratic attitude of relying on the 'healing power of nature' which he regarded as a mere 'meditation on death', and urged that active measures were needed for the process of cure to be 'seemly, swift and sure'. He founded a regular school at Rome which continued after him.

At first the school was the mere personal following of the physician, who took his pupils and apprentices round with him on his visits. At a later stage such groups combined to form societies or colleges, where problems of the art were debated. Towards the end of the reign of Augustus (27 B.C.–14 A.D.) or the beginning of that of Tiberius (14 A.D.–37 A.D.), these societies constructed for themselves a meeting-place on the Esquiline Hill. Finally the emperors built halls or *auditoria* for the teaching of Medicine. The professors at first received only the pupils' fees. It was not until the time of the Emperor Vespasian (reigned A.D. 70–9) that medical teachers were given a salary at the public expense. The system was extended by later emperors.

Thus Rome became a centre of medical instruction. After a time subsidiary centres were established in other Italian towns. From Italy the custom spread and we meet traces of such schools at the half-Greek Marseilles as well as at Bordeaux, Arles, Nîmes, Lyons, and Saragossa. For the most part these provincial schools produced workaday medical men, few of whose writings have come down to us. They were perhaps largely training-places for the army surgeons. That

class seldom had scientific interests, though Dioscorides, one of the most prominent physicians of antiquity, one who earned the respect of Galen and has deeply influenced the modern pharmacopoeia, served in the army under Nero. His book is, in fact, an extremely useful though ill-arranged compendium of drugs. Dioscorides wrote in Greek, and his work was not translated into Latin until the sixth century of our era.

The earliest scientific medical work in Latin is the *De re medica* of Celsus, which was prepared about A.D. 30. It is in many ways the most readable and well-arranged ancient medical work that we have. It is, however, not an original work but a compilation from the Greek, and the sole surviving part of a complete encyclopaedia of knowledge. Many of its phrases are closely reminiscent of the *Hippocratic Collection*. The ethical tone is high and the general line of treatment sensible and humane. Celsus, though almost forgotten in the Middle Ages, was the first classical medical writer to be printed (A. D. 1476).

The treatise of Celsus opens with an interesting account of the History of Medicine. It then passes on to deal with diet and the general principles of therapeutics and pathology, next it discusses internal disease, and then turns to external diseases. The last part of the work is devoted to surgery, and is perhaps the most valuable of the whole.

Celsus professes himself a follower of Asclepiades of Bithynia (p. 41), but, unlike his master, he by no means despises the Hippocratic *expectant* method of 'waiting on the disease'. In many matters we are struck with

his boldness as a surgeon. Thus he describes plastic operations on the face and mouth, and the removal of polypus from the nose. He tells too of the very dangerous operation for extirpating a goitre (p. 303), and of cutting for stone. He gives an excellent account of

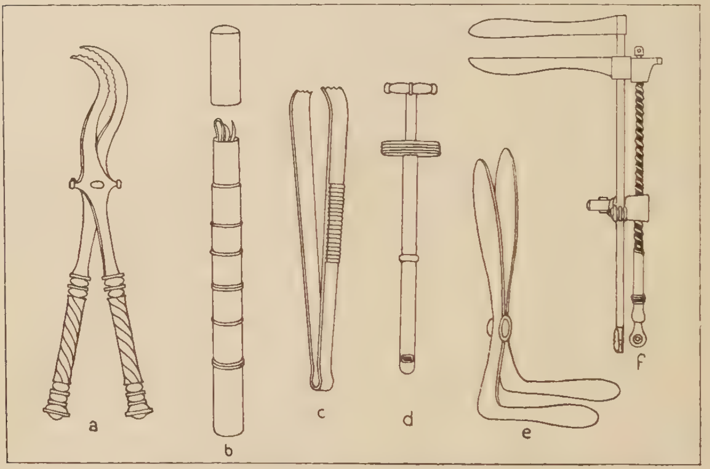


FIG. 15. ROMAN SURGICAL INSTRUMENTS of the first century A.D. found at Pompeii.

a. Forceps, probably for extracting teeth.
b. Small pocket-case of instruments containing sharp spoon, probe, &c.
c. Fine-toothed forceps.
d. Trocar and cannula for tapping fluids confined in cavities.
e. Speculum for examining orifices and cavities.
f. Instrument for dilating wounds that they may be more fully examined.

what might be thought the modern operation for removal of tonsils. Noteworthy also is his description of dental practice which includes the wiring of loose teeth and an account of a dental mirror. An idea of the surgical instruments in use in his time can be obtained from those recovered from Pompeii (Fig. 15).

§ 3. *Medical Services of the Roman Empire.*

If, in Medicine itself, the Roman achieved but few advances, in the organization of medical service, and especially in the department which deals with public health, his position is far more noteworthy. All Latin writers on architecture give much attention to the orientation, position and drainage of buildings. From an early date sanitation and public health drew the attention of statesmen. Considering the dread of the neighbourhood of marshes on the part of these practical sanitarians of Ancient Rome, and in view of modern knowledge of the mosquito-borne character of Malaria (pp. 284–5), it is entertaining to find the mosquito net ridiculed by the poets Horace, Juvenal and Propertius!

Sanitation was a feature of Roman life. Rome was already provided with *cloacae* or subterranean sewers in the age of the Tarquins (6th cent. B.C.). The *Cloaca Maxima* itself, the main drain of Rome, which is still in use, dates back to that period.

The antiquity of hygienic ideas is seen in an interdict, by a law of about 450 B.C., against burials within the city walls and in the instructions issued to the town officials to attend to the cleanliness of the streets and to the distribution of water. Among these ancient laws we may note one attributed to the first king of Rome, which directed the opening of the body in the hope of extracting a living child in the case of a woman dying in pregnancy. It is the origin of the so-called 'Caesarean section' on the living mother, the method by which Caesar himself is said to have been brought into the world. At the date of these decrees physicians in Rome

were either slaves or in an entirely subordinate position. Their status was improved by Julius Caesar (102–44 B.C.), who conferred citizenship on all who practised Medicine at Rome, in order to induce physicians to settle there.

The finest monument to the Roman care for the public health stands yet for all to see in the remains of the fourteen great aqueducts which supplied the city with 300,000,000 gallons of potable water daily. No modern city is better equipped (Fig. 16).

Under the early Empire a definite public medical service was constituted. Public physicians were appointed to the various towns and institutions. A statute of the Emperor Antoninus of about the year A.D. 160 regulates the appointment of these physicians, whose main duty was to attend to the poor. In the code of the Emperor Justinian (A.D. 533) is an article urging them to give this service cheerfully rather than the more subservient attendance on the wealthy. Their salaries were fixed by the municipal councillors. They were encouraged to undertake the training of pupils. Inscriptions attest the respect in which these state physicians were held in many towns.

It is in connexion with the army that we see the Roman medical system at its best. There was an adequate supply of military medical attendants who were well organized (Fig. 17). The defects of the Roman army medical system were, however, absence of any elastic scheme for the ranking of medical officers, and complete subordination of the medical to the combatant officer. These facts are of a piece with the general Roman indifference to theoretical science, and explain

16. AQUEDUCT OF NERO. This structure, when complete, conveyed part of the water supply of Rome.

(From an engraving by Piranesi.)

why the Roman army surgeons made no additions to knowledge. The social status of the medical staff in the Roman military hierarchy was that of the non-

FIG. 17. ROMAN ADVANCED DRESSING-STATION.
(*From Trajan's column.*)

To the left two Roman soldiers assist a wounded comrade. To the right a Roman military surgeon bandages the wounded thigh of a friendly ally. The costume of the surgeon is almost identical with that of the soldiers, though he carries a case for 'first aid' slung over his shoulder.

commissioned personnel, which included accountants, registrars and secretaries.

§ 4. *Roman Hospitals.*

The great contribution of Rome to Medicine—and it is a very great one—is the hospital system. It is a scheme that naturally arose out of the Roman genius for

organization and is connected with the Roman military system. Among the Greeks, *iatreia*, 'surgeries', were well known; they were, however, the private property of the medical man. Larger institutions were connected with Aesculapian temples and there is evidence of some degree of scientific medical treatment in these places. In the Republican period the Romans were no better off and, despite the vast numbers of slaves, there was no provision for them when sick. A temple to Aesculapius had been established on an island of the Tiber in Republican times. It became the custom to expose the sick and worn-out slaves on this island of Aesculapius, to avoid the trouble of treating them. The Emperor Claudius (A.D. 41–54) decreed that such slaves were free, and that, if they recovered, they need not return to the control of their masters. Thus, the island became a place of refuge for the sick poor. We may regard it as an early form of public hospital (Fig. 18).

Later writers speak of *valetudinaria*, 'infirmaries', for such persons, and give humane directions for their management. Such valetudinaria were in use even by free Romans. The excavations at Pompeii show that a physician's house might even be built somewhat on the lines of a modern 'nursing home'. It was probably in the provinces that private institutions first developed into subventioned public hospitals.

This development of public hospitals naturally early affected military life. At first, sick soldiers had been sent home for treatment. As the Roman frontiers spread ever wider this became impossible and military hospitals were founded at important strategic points. The sites of several such military hospitals have been

excavated. The best explored is near Düsseldorf and was founded about A.D. 100.

From the military valetudinarium it was no great step to the construction of similar institutions for the numerous Imperial officials and their families in the provincial towns. Motives of benevolence, too, gradually came in, and public hospitals were founded in many localities. The idea passed on to Christian times, and the pious foundation of hospitals for the sick and outcast in the Middle Ages is to be traced back to these Roman valetudinaria. The first charitable institution of this kind, concerning which we have clear information, was established at Rome in the fourth century by a Christian lady of whom we learn from St. Jerome. The plan of such a hospital projected at St. Gall in the early years of the ninth century has survived. It reminds us, in many respects, of the early Roman military hospitals. These medieval hospitals for the sick must naturally be distinguished from the even more numerous 'spitals' for travellers and pilgrims, the idea of which may perhaps be traced back to the rest-houses along the strategic roads of the Empire.

§ 5. *Galen.*

The Latin culture, as we have seen, did not adapt itself easily to the prosecution of scientific Medicine. Long after Greece had ceased to exist as an independent state such medical writings as appeared were usually in the Greek rather than in the Latin language. This is true to the end, and the end came, so far as creative science is concerned, with the second half of the second century. The scene is then, and for centuries to come,

FIG. 18. ISLAND OF ST. BARTHOLOMEW IN THE TIBER AT ROME. (*From an engraving by Piranesi.*)

The island was the site of a temple to Aesculapius used as a refuge for worn-out slaves. It is the first known public hospital. The entire island is carved in the form of a ship. On its prow can be discerned the head of Aesculapius and his staff and serpent.

mainly occupied by the huge overshadowing figure of Galen.

Galen of Pergamum (A.D. 130–200) devoted himself to medicine from an early age, and in his twenty-first year we hear of him studying anatomy at Smyrna. To extend his knowledge of drugs he made long journeys to Asia Minor. Later he proceeded to Alexandria, where he improved his anatomical equipment, and here, he tells us, he examined a human skeleton. His direct practical acquaintance with human anatomy was limited to that skeleton, for dissection of the human body was no longer carried on in his time. Thus, his physiology and anatomy were derived mainly from animal sources.

The general medical standpoint of the Galenic is not unlike that of the Hippocratic writings, but the noble vision of the lofty-minded, pure-souled physician has utterly passed away. In its place we have an acute, contentious fellow of prodigious industry, who is frequently satisfied with a purely verbal explanation. Yet he is an ingenious physiologist, acquainted with the internal parts, so far as this is possible from a devotion to dissection of animals, equipped with all the learning of the schools of Pergamum, Smyrna and Alexandria, and rich with the experience of a vast practice at Rome. Galen is essentially an 'efficient' man. He has the grace to acknowledge constantly his indebtedness to the Hippocratic writings.

Some of Galen's works are, however, mere drug lists, little superior to those of Dioscorides (p. 43). With the depression of the intelligence that corresponded with the break-up of the Roman Empire, it was these that

were chiefly studied and distributed in the West. The Greek medical writers after Galen were but his imitators and abstractors, and they usually imitated and abstracted Galen at his worst. Through some of them Galen's works reached the West at a very early period in the Middle Ages.

§ 6. *The Final Medical Synthesis of Antiquity.*

We now turn to the theoretical content of the vast mass of Galenic writings. These set forth a medical system of which the substance is based on the *Hippocratic Collection* and the form derived from Aristotle. This synthesis, in more or less corrupted form, provided the theoretical basis of medical practice for the next fifteen hundred years. Galen's view of the human body may be examined under two aspects, which we describe as (*a*) philosophical and (*b*) descriptive.

First as to the philosophical aspect. Galen's voluminous works are saturated with the theory that all structures in the body have been formed by the Creator for a known and intelligible end. In the anatomical works, masses of explanation, based on this view, dilute the often imperfect accounts of structures. Thus, following the Aristotelian principle that Nature makes nought in vain, Galen seeks to justify the form and structure of every organ—nay, of every part of every organ—with reference to the functions for which he believes it is destined. To do this is to claim that in every work of Creation—of which Man's body is a type—and in every detail of such work, we can demonstrate God's design along known principles. It is to claim, in fact, a complete knowledge of the Laws of Nature.

No modern man of science, however intoxicated with his own achievements, has as yet arrogated such powers to himself. To conceive that such claims should be made by a pious, theistically minded author, the reader must think himself back into a very different philosophical environment from that to which we are nowadays accustomed.

The prevailing philosophy of Galen's world was the Stoic. Now in the world of the Stoic philosopher all things were determinate, and they were determined by forces acting wholly outside Man. The type and origin of that determination the Stoic sought in the heavens, and found in the majestic and overwhelming procession of the stars. The recurring phenomena of the spheres typified, foreshadowed, nay, exhibited and controlled, the cycle of man's life. Man dwelt in a finite world, bounded by a definite frontier—the sphere of the fixed stars. Within that spherical frontier all things worked by rule—and that rule was the rule of the heavenly bodies. Astrology had become one of the dogmas of the Stoic creed.

To such a world Galen's determinism was in itself no strange thought. Yet Galen's view was far from being wholly in accord with Stoicism. Though a determinism, it was a determinism of perfection in which all was fixed by a wise and far-seeing God, and was a reflection of His perfection. Now such a scheme did not ill fit the new creed which was just beginning to raise its head and was destined to replace Stoicism and all the other pagan schemes. Galen's thought, in fact, made a special appeal to the Christian point of view, and this is, doubtless, the reason that his works have

been preserved in larger bulk than those of any other pagan writer. The Galenic standpoint appealed equally to the theological bias of Islam, whose medical knowledge was based almost entirely on Galen.

We may now turn from the philosophical to the descriptive bases of Galen's medical system, namely to his Anatomy and Physiology.

We may begin with the bones. These Galen had studied on an actual human skeleton at Alexandria. He divided them into long bones with a central canal and flat bones without such a canal. He had a fairly good idea of the bones of the skull. He regarded the teeth as bones, and he gives a good description of their origin. He recognized twenty-four vertebrae terminated by the *sacrum*. Galen gives accurate elementary descriptions of the vertebrae, of the ribs, of the breastbone, of the collar-bone, and of the bones of the limbs. He divides joints or junctions of bones into two main orders, those with movement and those without movement, and the titles that he gives to his main divisions have survived in our modern nomenclature.

As regards the muscular system there can be little doubt that Galen's work was in large part of a really pioneer character. Throughout his works the muscles are perhaps the structures that he describes most accurately. His writings contain frequent references to form and function of muscles of various animals. Thus, the dissection of the muscles of the orbit and larynx was performed on the ox, and the muscles of the tongue are described from the ape. Occasionally he indicates that he is aware of the differences between certain of the muscles he is describing from those of man. For his

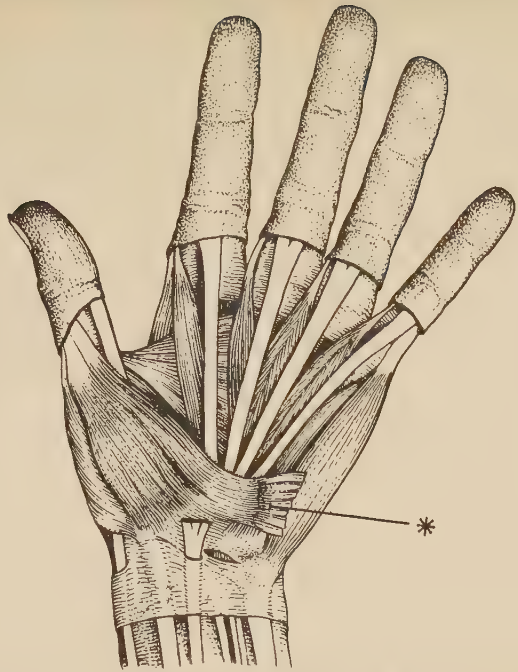
investigation of muscles Galen used particularly the Barbary ape (*Macacus inuus*), a creature anatomically near enough to man for a knowledge of its detailed structure to be applicable to human Surgery. (Figs. 19 and 20.)

Galen's description of the brain and of the vascular system is inferior to his account of the bones and muscles. His account of the nervous system, other than the brain, occupies an intermediate position. His account of the origin of nerves from the brain has left its traces even in modern descriptive anatomy.

Finally we may turn to Galen's theory of the working of the human body, that is to his Physiology.

The basic principle of life in the Galenic physiology was a *spirit* or *pneuma* drawn from the general World-spirit in the act of breathing. It entered the body through the windpipe or *trachea* and so passed to the lung and thence, through the *arteria venalis*—which we now call the 'pulmonary vein'—to the left ventricle of the heart, where it encountered the blood (Fig. 21). But what was the origin of the blood? To this question his answer was ingenious, and the errors that it involved remained till the time of Harvey (Fig. 41, p. 113).

Galen believed that food-substance from the intestines was carried as 'Chyle' by the portal vein to the liver. There it was converted into blood and endowed with a particular pneuma, the *Natural Spirit*, which bestowed the power of growth and nutrition. Part of this lower-grade blood was carried from the liver to the right ventricle, where it gave off impurities by way of the *vena arterialis*, our 'pulmonary artery', to the lungs, whence they were exhaled in the breath. The venous



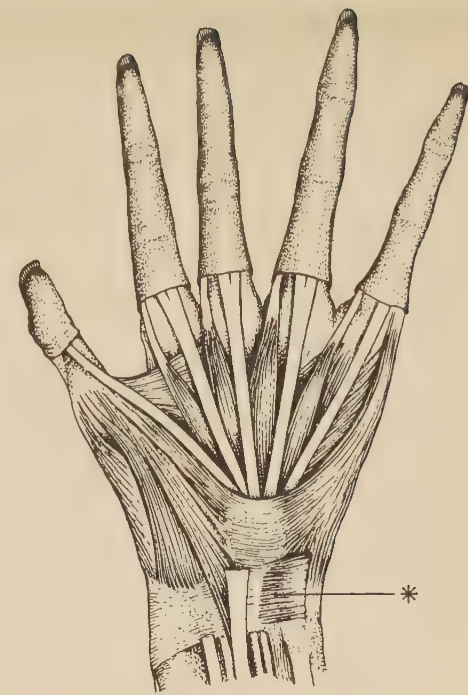


Fig. 19. DISSECTION OF HAND OF MAN. Fig. 20. DISSECTION OF HAND OF BARBARY APE. The ape's hand shows all the main muscular and tendinous structures present in the human hand, though the proportional development differs somewhat. The same is true of other parts of the body. Galen's anatomy, drawn from the Barbary ape, was thus quite serviceable for many surgical procedures. Apart from proportion, the most obvious anatomical difference in the hands of the two species is the position of attachment of the small severed muscle indicated by the asterisk in both cases.

blood, thus continuously purified, ebbed to and fro in the veins for purposes of ordinary nutrition. A very small part of this venous blood passed through invisible pores in the muscular septum to the left ventricle. There it mixed with air drawn in from the lung by way of the *arteria venalis*, our 'pulmonary vein'. From this mixture was produced a higher-grade blood, the arterial blood, instinct with the principle of life and charged with a second kind of pneuma, the *Vital Spirit*. Blood containing this second kind of pneuma ebbed to and fro in the arteries endowing the various organs with function. Such as reached the brain became there charged with the noblest essence of all, the third pneuma, the *Animal Spirit* or breath of the soul. The *Animal Spirit* was carried from the brain by the nerves —believed to be hollow—and through them initiated the higher functions of the organism, including motion and sensation (Fig. 21).

Among Galen's most remarkable efforts are the investigations he made of the physiology of the nervous system. He tells of his experiments on the spinal cord. Injury to the cord between the first and second vertebrae caused, he observed, instantaneous death. Section between the third and fourth produced arrest of breathing. Below the sixth vertebra it gave rise to paralysis of the chest muscles, breathing being then carried on only by the diaphragm. If the lesion was lower the paralysis was confined to the lower limbs, bladder, and intestines. The physiology of the spinal cord is worked out most ably and in very considerable detail.

Galen established no school, nor had he any definite followers. His self-satisfaction and love of controversy

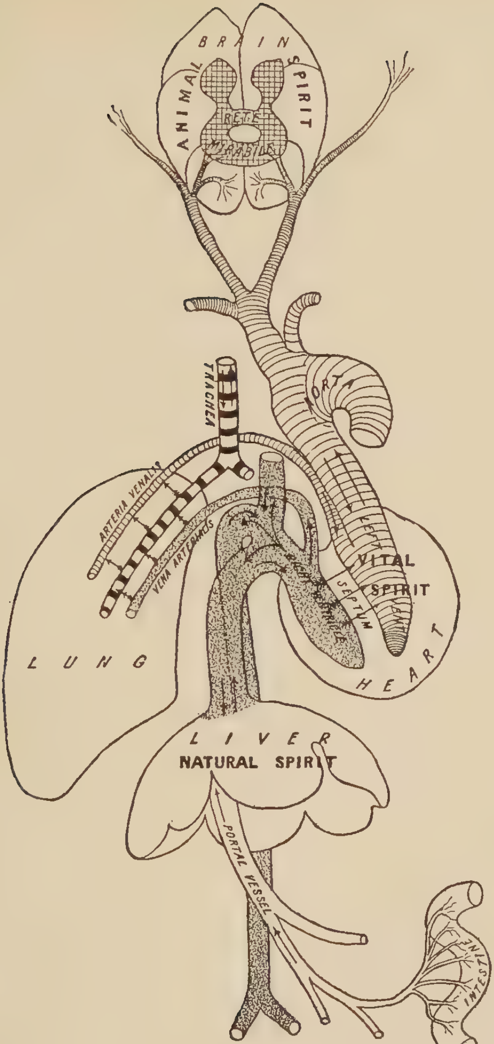


FIG. 21. GALEN'S PHYSIOLOGICAL SYSTEM

were not of the kind that would endear him to disciples. On his death in A.D. 200 the active prosecution of anatomical and physiological inquiry ceased absolutely. The curtain descends at once, and, for the subject we are discussing, the Dark Ages have begun.

Rational medicine in the pagan world descends into darkness as surely and even more abruptly than Philosophy. The whole system is soon to be overwhelmed. Alexandria has long been in decline. A mob, fanatically Christian, has destroyed her school and library, with all the hoarded wisdom of the pagan past. Men of the new faith fix their eyes on the wrath to come and the glory after it. In the race for salvation, who will pause to consider this miserable tenement of clay? Antiquity is no more. A new age has begun.

III
THE MIDDLE AGES

(FROM ABOUT A.D. 200 TO ABOUT A.D. 1500).

§ 1. *The Period of Depression in Europe.*

THE observational period of Antiquity closed with Galen. The centuries that follow exhibit progressive deterioration of the intellect. For that deterioration many causes have been assigned. An important factor was certainly the philosophical outlook of later paganism. Men lacked a motive for living. Their view of the World was dreary and without hope. It is sometimes alleged that the advent of Christianity was a factor in the decay of Science, but Science was, in fact, in headlong decay before Christianity was in a position to have any real effect on pagan thought.

Christianity came to the ancient world as a protest and a revulsion against the prevailing and extremely pessimistic pagan outlook. Christianity brought men something for which to live. It was natural that it should oppose the philosophical basis of pagan thought. In this sense Christianity was certainly anti-scientific. Early Christian thought exhibits an aversion to the view which places the whole of man's fate under the dominion, the inescapable tyranny, of Natural Law. It is, however, essential to remember that the early Church, in developing this opposition, was not dealing with living observational Science. The conflict was simply with a philosophical tradition which contained dead, non-progressive and misunderstood scientific elements.

For some eight centuries from the time that Christianity finally replaced Paganism in the Roman Empire —from about A.D. 400 to about A.D. 1200—such remains of classical learning and classical science as survived were in monastic keeping. It was only in the monasteries that there were any who cared at all for these things, and it was only in the monasteries that manuscripts could be either written or preserved. We cannot be sufficiently grateful to the monks for having succeeded in preserving even as much as they did. Nevertheless, whether we consider what they saved or what they lost of medical literature, we can express no high opinion of either monastic taste or monastic judgement.

The curse of the Science of Medicine, as of all sciences, has always been the so-called 'practical man', who will consider only the immediate end of his art, without regard to the knowledge on which it is based. Monkish medicine had no thought save for the immediate relief of the patient. All theoretical knowledge was permitted to lapse. Anatomy and Physiology perished. Prognosis was reduced to an absurd rule of thumb. Botany became a drug-list. Superstitious practices crept in, and Medicine deteriorated into a collection of formulae, punctuated by incantations, which became less understood and further removed from their originals at each copying. Medicine remained surrounded by sacred associations (Fig. 22), but the scientific stream, which is its life-blood, was dried up at its source.

There was just one area in the Latin West where a slightly higher standard prevailed. In the South of

Italy the Greek tongue still continued for centuries to be spoken and written. Though civilization had sadly deteriorated with the disorders of the times, yet there

FIG. 22. EARLIEST KNOWN REPRESENTATION OF ST. LUKE AS A PHYSICIAN. From a seventh-century painting in the underground basilica of Saints Felix and 'Adauctus' at Rome. St. Luke, as an Evangelist, holds a scroll between his hands; as a Physician he carries suspended from his left arm a bag containing four instruments, one of which is a lancet. The head is tonsured like a monk's. By courtesy of Rev. Father J. R. Fletcher.

FIG. 23. PICTURE OF TREPHINING from a thirteenth-century manuscript. The surgeon is using a well-known and primitive form of drill, the mode of action of which will be understood by the accompanying diagram, shown as Fig. 24.

remained here and there in that region a slightly higher intellectual standard than prevailed elsewhere in Europe. Moreover, about the same time as the Norman Conquest in England, there was a Norman Conquest

of South Italy also. The strong arm of the Norman administrator might wield the weapon of a tyrant, but at least it brought order where there had been anarchy. Learning under the Normans could lift a timid head. Notably at the town of Salerno, not far from Naples, there arose something resembling a medical school. At Salerno in the eleventh century there was a certain amount of translation of medical works from Greek into

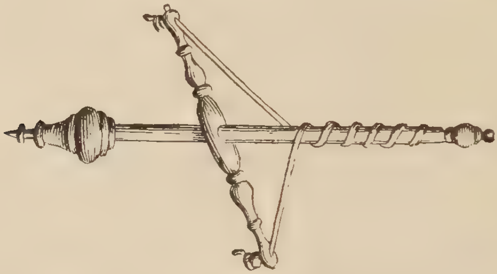


FIG. 24. FIGURE to illustrate the mode of action of the instrument used by the surgeon in Fig. 23. The twist of the thong causes rapid rotation of the axis. The rotating point is pressed on the skull and gradually penetrates it. From a drawing of the sixteenth century.

Latin. The choice of works for translation was very poor, but it was something that enough mental energy existed for the effort.

Salerno differed too from other centres of learning of the time in that instruction was not entirely under monastic auspices (Fig. 25). Some, at least, of the Salernitan physicians were laymen. At the time of the Norman conquest of Salerno, the school was stimulated by the advent of a wanderer from the East, Constantine by name (died 1087). This man brought with him medical works in Arabic which he was able to translate into rude Latin. The Latin versions prepared by Constantine,

corrupt, confused, barbarous, often almost incomprehensible, were yet a better intellectual fare than that on which the torpid mind of Europe had long fed. The Salernitan medical writings of the eleventh and

FIG. 25. SCENE AT A SIEGE OF SALERNO from a manuscript prepared in South Italy early in the thirteenth century. An archer transfixes two of the defenders through the cheeks. A *medicus* is aiding one of them. Two nurses, bearing drugs and dressings, attend the medicus. It illustrates the existence of lay physicians at Salerno at this date. The medicus is not tonsured.

twelfth centuries exhibit some faint-hearted attempts to return to Nature. Constantine was but the harbinger of the great 'Arabian revival' the further origins of which we must now seek to trace.

§ 2. *Arabic Medicine.*

Barbarian incursions sapped and finally destroyed the Western Roman Empire. The influence of those incursions on the Eastern Empire was less dramatic. It is true that the intellectual outlook of the East Roman or Byzantine Empire was no less modified, in the course of time, than was that of the West. In the absence, however, of any collapse of the system of government, the ancient Greek learning, or rather the documentary casing in which it was enshrined, was better preserved than were the Latin traditions. Men in the Eastern Empire could still read the ancient Greek medical works in the language in which they had been written, and, if their reading was unintelligent, it was at least persistent. Moreover, heretical Christian sects on the confines of the East Roman Empire prepared for themselves translations of many of the ancient Greek authors. One of these heretical sects, the Nestorians, exhibited great missionary activity. It was perhaps on this account that the Nestorians prepared translations of many Greek medical works into their own language, Syriac.

In the seventh century, Islam arose and soon swept over vast areas that had erstwhile belonged to the Emperor of the East. The territory occupied by the Nestorians in the Near East came early under Moslem rule. The Moslems, at first indifferent to infidel learning, came gradually to appreciate it. In the ninth century a great and united Moslem Empire was established with its centre at Bagdad. The need for translation of Greek scientific works into Arabic, the common lan-

guage of Islam, now asserted itself. One after another the medical writings that had been turned into Syriac were translated into Arabic, and Greek Science in general and Greek Medicine in particular were thus spread far and wide in the Moslem world.

Greek science in the Arabic version came in time to be better understood by Arabic-speaking students than it had been by any since Galen. Nor were the Arabic-speaking peoples content to rest on the texts that had thus descended to them from antiquity. A considerable number of Arabic writers produced works of their own, some not wholly devoid of originality. Unfortunately these men were without effective anatomical or physiological basis for their medical knowledge, though many of them were acute clinical observers, and, even from the modern point of view, some of their works are not wholly contemptible. Thus Rhazes (860–932), a native of Basra on the Persian Gulf, wrote a work containing the first known description of Measles, which he carefully distinguishes from Small-pox. The Persian Avicenna (980–1036) composed a vast encyclopaedia of medical knowledge, the so-called *Canon*, which served as the main text-book of Medicine both among the Arabic-speaking peoples and in the Latin West until the seventeenth century. The Jew, Isaac of Kairouan (852–952), composed a treatise on fevers which was the best account of the subject available in Europe during the entire Middle Ages. The Moor, Albucasis (11th cent.), left a text-book of surgery which was an important element in the revival of the subject in Italy and France.

These are only prominent members of a vast school

of writers who flourished in Arabic-speaking countries between the ninth and thirteenth centuries. The bulk and number of their writings is portentous. Many of their works were translated into Latin, often by Jewish translators (Fig. 26). These Latin translations caused a reawakening of the intellect of Europe, and provided the staple reading in the medieval universities throughout the Middle Ages.

§ 3. *The Medieval Awakening.*

The Spanish peninsula had been inundated by the Islamic tide as early as the eighth century. After a while the waters began to recede. The speech and culture of Islam had become stamped upon the natives of the peninsula, and were only gradually replaced by the Latin civilization and dialect which we now call Spanish. During the centuries of Islamic retreat, there was thus a bilingual population in the peninsula, so that access to the Arabic learning became possible. The translations that were to have influence on Europe were always into Latin. To make or to obtain such translations many adventurous spirits journeyed from Christian Europe into Spain, or sometimes into Sicily where conditions were very similar. These men were aided in their work by native Jews or by Mohammedans. The heretical company which they kept, together with the strange and mysterious material which they brought back with them, earned them a reputation as magicians. The memory, for instance, of Michael Scot is connected with the Black Art, and has been presented by Sir Walter Scott in his poem *The Lay of the Last Minstrel.*

The wizard Michael Scot (died 1235) journeyed in

both Spain and Sicily, learned Arabic and Hebrew, and had commerce with Mohammedans and Jews. He turned a number of Arabic works into Latin, and, in particular, he prepared versions of the biological works of Aristotle (pp. 28–33) which, though corrupt and second-hand, had much influence in determining the direction of medical thought during the Middle Ages.

FIG. 26. A JEWISH TRANSLATOR receiving an Arabic medical volume from an Eastern potentate (right) and handing it, translated into Latin, to a Western monarch (left). From a thirteenth-century manuscript.

There was a large class of such translators and commentators who made Arabic Medicine accessible to the West. This Arabic-Latin literature is generally characterized by the qualities most often associated with the words *medieval* and *scholastic*. It is extremely verbose and almost wholly devoid of the literary graces. An immense amount of attention is paid to the mere arrangement of the material, which often occupies its authors more than the ideas that are to be conveyed. Great stress is laid on argument, especially in the form of the syllogism, while

observation of Nature is entirely in the background. Above all, there is a constant appeal to the authority of the ancient masters, especially Aristotle and Galen. Lip service is often paid to Hippocrates, but his spirit is absent from these windy discussions.

When the Latin translations from the Arabic reached the readers for whom they were intended, they were eagerly studied. The texts were, however, by no means permitted to remain in their pristine state, but were submitted to exactly the same process to which their Arabic authors had themselves subjected their Aristotelian and Galenic models. The Christian writers of the West treated the Latin translations of Rhazes, of Avicenna, of Isaac and of Albucasis (p. 67), as subjects for commentary. Their works were expanded, annotated, castigated again and again, and without any new inflow of ideas. The result is a progressive elaboration of form and deterioration of content throughout the centuries. Vast masses of argument, rebuttal, refutation and confirmation drowned again the human spirit which hardly recovered from its submersion until the sixteenth century.

§ 4. *The Universities.*

Nevertheless, when these translations were new to Europe, and especially in the thirteenth century, they caused much stir. In this awakening a large part was played by the Universities. These were established in numbers during the thirteenth and the following centuries. University life gradually came to exercise a profound effect on social, political and intellectual conditions. In most of the Universities Medical

Faculties grew up. The medical teaching was entirely theoretical and there was no clinical instruction, though at the beginning of the fourteenth century some advance was made by the introduction of brief and superficial anatomical demonstrations (p. 74).

As a type of Medieval University, we may take Bologna, which was an important centre of learning from a very early date (Fig. 27). As the Universities multiplied, they began to some extent to 'specialize'. Bologna had appeared first as a Law school and continued to develop along the same line. In the second half of the thirteenth century it was by far the most important seat of legal learning in Europe.

An organized Medical Faculty existed there as far back as 1156. The teaching at Bologna, as in other medical schools, consisted entirely of readings of Latin translations from Arabic which were becoming ever more accessible. Yet it was at Bologna that public dissection was first practised. The early advent of dissection has often impressed the historian. There was still no botany worthy of the name, no zoology, hardly any naturalistic art, no experimental science, no systematic record of observation in any department. Yet dissection had become recognized at Bologna by the end of the first quarter of the fourteenth century. The question is why men, so little interested in Nature and Nature's ways, should have lent themselves to so repellent a process as dissection of the human body? The answer is that the earliest reason for examining the human body was simply the gathering of evidence for legal processes. As time went on, post-mortem examination passed into anatomical study. But still dissection

did no more, and was asked to do no more, than verify Avicenna—whom nobody doubted. It was, in fact, little but an aid to the memory of students.

At Bologna we can trace the rise of a surgical school beginning about the end of the twelfth century. Prominent among its early surgeons was William of Saliceto (1215?–1280?). He wrote a very able treatise on Surgery, containing a section on Anatomy. The anatomical portion is borrowed from the current Arabian anatomies, but contains some evidence of direct access to the dead human body. He includes in his work a good description of trephining the skull (Fig. 23).

A most interesting contemporary of William of Saliceto was Thaddeus of Florence (1223–1303), who also taught at Bologna. This man perceived the importance of access to Greek sources, as distinct from Graeco-Arabic, and he encouraged the preparation of good Latin translations of medical works direct from the Greek. He stamped his personality on the whole development of Medicine at Bologna, and he is bound up with the beginning of dissection. But if Medicine owed a debt to Thaddeus for introducing better texts and better Anatomy, he did grave harm to the subject in another direction. The scholastic and argumentative form assumed by medieval Medicine is largely due to him, and it is to the assumption of this form that we owe the almost complete absence of scientific advance between the thirteenth and sixteenth centuries.

§ 5. *Medieval Anatomy, Surgery and Internal Medicine.*

At the very end of the thirteenth century there came to Bologna a Norman student, Henri de Mondeville

FIG. 27. MEDIEVAL BOLOGNA, from a mural painting of about 1500 in the town-hall of the city. The city contained a number of towers, nearly all of which have now been destroyed.

(about 1270–1320). In 1301 he settled at the famous Medical School at Montpellier in Southern France, and thus transplanted to France the medical, surgical and anatomical traditions of Bologna. Those traditions were of Arabic origin, and mainly borrowed from Avicenna.

Contemporary with de Mondeville was one whose method of teaching shines as a good deed in a naughty world. Mondino di Luzzi (*c.* 1270–1326) was a pupil of Thaddeus and a fellow-student of Henri de Mondeville. He worked systematically at Anatomy and dissected the human body in public. His treatise on Anatomy, written in 1316, is the first modern work on the subject. Those who preceded him incorporated their anatomical work in larger treatises on Surgery, and do not refer directly to their own anatomical experiences. With Mondino this is changed. His work is essentially a practical manual of the subject and he is with justice called the 'Restorer of Anatomy'. He had read widely among the Arabian anatomists, and naturally borrowed from them. Nevertheless, his work contains a considerable number of references to actual anatomical procedure. Moreover, he deals not only with Anatomy in our modern sense, but also includes Physiology and much discussion of the application of anatomical and physiological principles to Medicine

Description of Fig. 28

The professor stands in his 'chair', a great pulpit or 'cathedra', reading from his book—hence the English academic titles 'Reader' and 'Lecturer' or 'Lector' (that is, 'one who reads'). The body is dissected by a menial, whose work is guided by an assistant, who, with wand, points out (Latin *demonstrat*, hence our modern title *Demonstrator*) the lines of incision. Students in academic dress stand around, but do not themselves dissect.

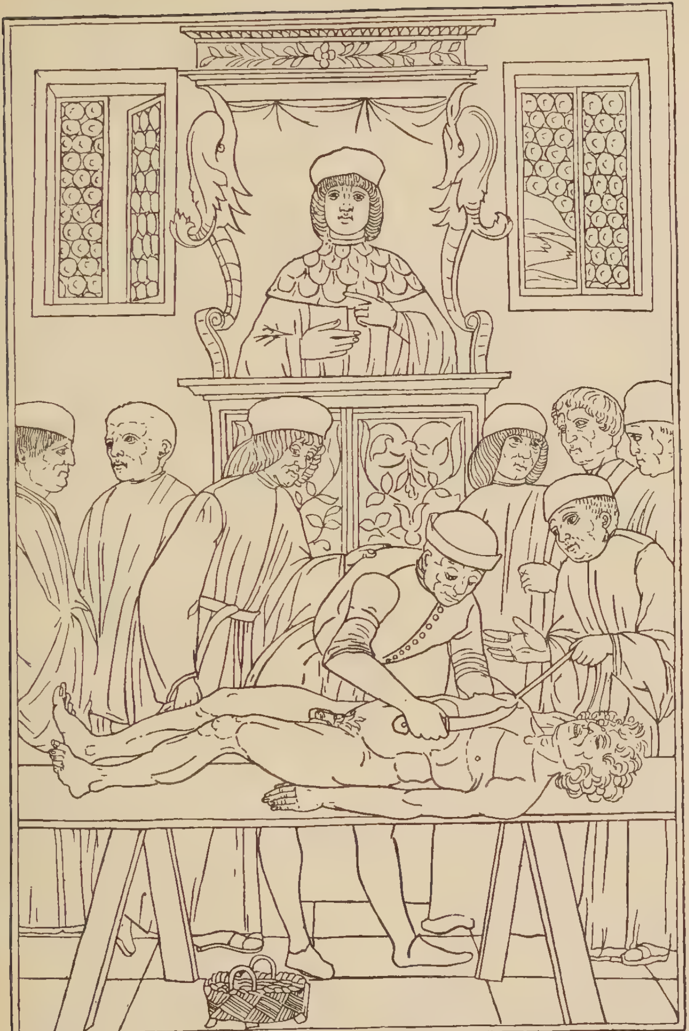


Fig. 28. AN ANATOMICAL LECTURE AT PADUA in the fifteenth century, from a contemporary Italian woodcut. See note opposite.

and Surgery. His book thus gives a good deal of insight into the scientific knowledge of the day.

We would emphasize the fact that Mondino dissected *in person*. In this respect he was wiser than his successors until the time of Vesalius. As dissection gained formal inclusion in the curriculum, the professor became more haughty, further removed from the object of his study. Leaving his position by the body, where he might demonstrate to his students, he ascended his high professorial chair, a great elevated structure provided with steps and a reading-desk. From there he read from his text-book while a junior colleague pointed out the line of incision and a menial performed the actual dissection (Fig. 28). All was thus done at third-hand and according to the written word. We are in the scholastic period, and must not expect any frequent appeal to Nature. Having once got into his chair, it took a good deal to persuade the professor to descend from that dignified position. Thus, it is saying much for Mondino that he was his own demonstrator. He took the first and perhaps the greatest step. It was two centuries and more before the next step was taken.

Most typical of medieval surgeons was Guy de Chauliac (1300–68), who studied at Montpellier, Paris, and Bologna, and practised at Montpellier and afterwards at Avignon, where he was a member of the Papal Court. He was a man of much learning, and his *Great Surgery* became the standard treatise on the subject during the later Middle Ages. It fixed medieval practice. It is to be found in scores of manuscripts and was frequently translated and printed. Among the good points of his practice is his acceptance of responsi-

bility for certain operations, such as those for rupture and for cataract, which at that time were usually left to wandering charlatans who regarded themselves as specialists. A famous passage in his work describes the use of a narcotic inhalation frequently used during the Middle Ages and into modern times. Of such a narcotic it is written that:

> I'll imitate the pities of old surgeons
> To this lost limb, who, ere they show their art,
> Cast one asleep, then cut the diseased part.

(Thomas Middleton, *Women beware women.* First acted 1622.)

The general character of Internal Medicine during the later Middle Ages was below that of Surgery. Modern clinical Medicine is firmly based on such sciences as Physiology, Pharmacology, Pathology, Biochemistry and Epidemiology. In the Middle Ages and far beyond, Physiology was still that of Galen, which had lost in exactness what it had gained in bulk from the Arabic and Latin commentators. Pathology was still that of the four humours. The knowledge of drugs was empirical, and the sciences of Pharmacology and Biochemistry as yet were not; while the medieval conception of the nature of epidemics was the very perversion of reason and common sense. Nevertheless, as we shall see, the Middle Ages ultimately succeeded in instituting a limited number of effective preventive measures.

§ 6. *Medieval Hospitals and Hygiene.*

Undoubtedly an important development of medieval Medicine is its hospital system. The public hospital arose in pagan antiquity out of the Temples of Aescula-

pius and the military valetudinaria (p. 49). The conception was seized on by Christianity and developed beyond all knowledge. In the early Christian centuries, *hospitalia*, 'guest chambers' or 'guest houses', were set aside for the numerous *hospites*, or 'pilgrims'. Similar buildings under the same title came to be instituted for the care of orphans, the aged, the blind, and other victims of fortune. Thus arose the medieval hospital system, of which ours is the direct outgrowth.

In matters of Hygiene the Middle Ages are a byword. The health conditions of a medieval town were far below those of the same town under the Roman Empire. Water supply was deficient, drains were absent, streets and houses filthy and overcrowded, rooms unventilated. Nevertheless, there is one important hygienic conception for which our own age owes a considerable debt to that which preceded it. Despite their scientific acumen in many departments, it is yet true to say that among the physicians of classical antiquity we find no consistent view of the transmission of infection by contact. Indeed the whole idea of infection was effectively absent from them, so that preventive measures based upon it could not be developed. It was reserved for the Middle Ages to conceive serious official measures against the spread of epidemics. These measures were consciously derived from the leper ritual of the Bible with its fundamental concept of isolation.

During the early centuries of the Christian era, Leprosy, which had till then been confined to the East, crept along the Mediterranean littoral and thence northward throughout Europe. The disease was from the

first regarded as contagious, and various regulations were introduced to isolate and separate the unfortunate sufferers. The medieval treatment of lepers is one of the dark incidents of man's inhumanity to man. The leper was banished from human society. He was

FIG. 29. A HOSPITAL WARD in sixteenth-century Paris. In the left aisle, a nun folds the hands of a dying patient, while a priest gives the Sacrament to another in the same bed. In front, nuns sew shrouds. The right aisle is more cheerful. Nuns minister to two patients in one bed, while a convalescent, fortunate in having a bed to himself, vigorously takes nourishment. In the centre, nuns receive postulants and a royal founder kneels in prayer.

declared legally dead. He was excluded even from church or allowed to attend only in special seats where a special basin of holy water was assigned to him. How rigorously this segregation from the ranks of free people was carried out by law is well known. The cruel edicts were, however, effective. In the course of cen-

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turies it freed Europe from Leprosy, of which it is said there were at one time some 20,000 cases in France alone. Thus about one person in 200 would have been a leper, and the burden of the leper on the community was comparable to that, let us say, of the feeble-minded and insane with us.

Leper inspection, the regular examination of all suspects and carriers of leprosy, became a most elaborate business. It was entrusted to a special branch of the civil service and was gradually freed from ecclesiastical control.

This preventive method of combating a chronic disease, which, as we know now, has a very low infectivity, had a peculiar and unlooked-for result. The meticulous system of warding off the contagion of leprosy so occupied the attention of physicians that they came to see allied conditions in the same light. So it was that in the thirteenth century the general concept became current of disease as contagious. A number of other diseases besides leprosy were recognized as infectious. Among these were Plague, fevers with obvious rashes, Phthisis, Granular Conjunctivitis, the Itch and Erysipelas. Municipal authorities were from time to time ordered to put patients suffering from one or other such diseases outside the city gates. They were forbidden to traffic in articles of food and drink and were placed under restrictions not unlike those of lepers. The devastating epidemic of the Black Death of 1347–8 brought restrictions of this order into special force. Thus the Black Death had somewhat the same effect on the health administration of the day that the Cholera outbreaks of the thirties of the nineteenth cen-

tury had upon modern Europe. The health service began to be put into more efficient order.

In the later Middle Ages there were actually instances in which the Pest was averted or successfully combated by these means. This seems to have been the case at Milan and Venice between the years 1370 and 1374. At that time the Plague was again advancing through Europe. The most drastic regulations were invoked to prevent infected persons from entering the cities, and these regulations came into force well in advance of the disease.

There is one incident in this medieval attempt to prevent Plague that has left a mark on our language. The Republic of Ragusa, on the eastern side of the Adriatic, adopted and extended the regulations that had been so successful at Venice. A landing-station was established far from the city and the harbour. There incoming suspects had to spend thirty days in the open air and sunlight, and any who had traffic with them were isolated. The period of thirty days was spoken of as the *Trentina*. Later this was found to be not long enough. The thirty days became forty days, the *Quarantina*, whence we have the word *Quarantine*. The system of quarantine gradually spread through Europe. It was accompanied by very drastic destruction, by burning, of all goods belonging to the infected.

These attempts to arrest epidemic disease were sometimes successful and the elaboration of quarantine measures was among the few advances with which we may credit the Middle Ages. The fact that we can now dispense with quarantine must not blind us to its value in conditions other than our own.

IV

THE REBIRTH OF SCIENCE

(FROM ABOUT 1500 TO ABOUT 1700)

§ 1. *The Anatomical Awakening.*

DURING the Middle Ages beliefs about physiology were always based on Galen. They were frequently confused and often the result of a misunderstanding of his work. In the fifteenth century, however, took place the so-called *Renaissance* or *Revival of Learning*. Greek works which had been trickling in since the thirteenth century began to be recovered more rapidly, and to be more accurately studied. The first step towards any improvement on the views of Galen was naturally a proper understanding of what he had really said. For that there was needed a better knowledge of Greek than had been possessed by the Middle Ages. In the fifteenth century Greek scholarship made great advances and there was enthusiasm for classical learning. Accurate translations of the Greek works of Galen were made. The printing press was invented about the middle of the fifteenth century. Towards its end printed copies of the improved translations began to appear. So it came about that the Revival of Learning produced a revival of the ancient scientific knowledge.

This scientific revival led to a new interest in Anatomy. During the Middle Ages the occasional dissections at the Universities were merely supposed to illustrate Avicenna and Galen (Fig. 28 and p. 72). Dissection became much more widely practised in the fifteenth century, but it was nearly the middle of the

sixteenth century before any real and open discussion of Galen's views took place in the Universities.

There were, moreover, other influences at work. Along with the revival of learning there was also a renaissance of art. Some of the great Renaissance artists—Michelangelo, Raphael and Dürer among them—began to study the human form very closely. They soon found that to represent it accurately some knowledge of Anatomy, and especially of the bones and muscles, was needed. The artists, therefore, began also to dissect. Among these great artists were some who took more than a purely artistic interest in the structure and workings of the body. Of these the most important for us was Leonardo da Vinci (1452–1518). He was a man of enormously powerful and inquiring mind, and his achievements in science are at least as remarkable as his works of art. He had determined to write a text-book of anatomy and physiology. Though he did not publish it, many of his beautifully illustrated notebooks on these subjects have survived.

Leonardo was the first to question the views of Galen. He made careful first-hand investigations on the bodies of men and animals, and performed many physiological experiments. Though a man of the most lofty genius, centuries ahead of his time, yet his outlook is, in many respects, typical of his age. His interest in anatomical investigation is therefore not surprising, for such inquiries were then astir. It happened that he was particularly interested in the heart and blood-vessels. He reached the correct conclusion that, contrary to Galen, the branches of the air-tubes in the lungs do not come into relation with the heart, but, after branch-

ing and gradually diminishing in size, they finally end *blindly*. He inflated the lungs with air and found that, whatever the force used, air could not be driven from the air-tubes into the heart. He therefore inferred quite correctly that Galen's *arteria venalis* (our 'pulmonary vein') did not convey air to the heart, as the followers of Galen believed.

Leonardo then turned to examine the structure and form of the heart itself. He prepared more accurate drawings of it than had been made by any before him, making sections and dissections and examining its valves (Fig. 30). Ultimately he succeeded in grasping the nature and action of the valves at the root of the great arteries as they arise from the heart, and he verified his view by remarkable experiments. He proved that the valves allowed the blood to pass in only one direction, and prevented its regurgitation. Yet Leonardo gives no complete or clear description of the action of the heart. He could not emancipate himself from the old idea of the passage of the blood from the right ventricle through the septum into the left ventricle (Fig. 21), though he sometimes seems doubtful about it.

It must be remembered that Leonardo did not publish his researches. It is only recently that his note-books have become fully accessible. But although Leonardo's work remained in manuscript, it must not be assumed that his views were wholly without effect on his contemporaries. At any rate, soon after his time the questions that he had raised concerning the heart and blood-vessels were attracting others and were generally regarded as forming an important problem needing solution.

The task of writing an anatomical text-book based on direct observation, to which Leonardo did but put his hand, was achieved by one who was only four years old at the time when the great artist died. The central

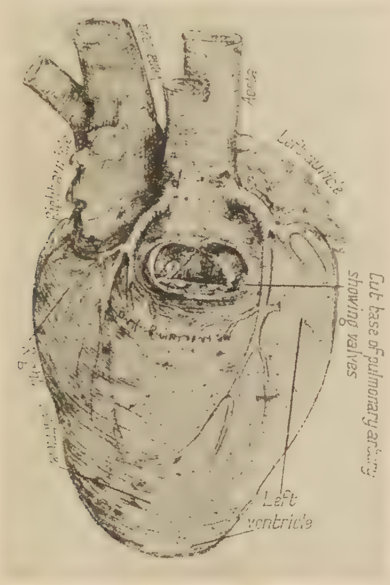


FIG. 30. DRAWING OF DISSECTION OF THE HEART by Leonardo da Vinci. The modern names of some of the more important parts have been added.

place in the unfolding drama is occupied by Andreas Vesalius of Brussels (1514–64). This extraordinary man studied first at the University of Louvain and afterwards at Paris. Anatomical instruction at these Universities had not improved much, if at all, on that of the Middle Ages. Vesalius soon tired of hearing long passages of Galen read out by the professor. He

therefore resolved to go to northern Italy, where newer methods were being practised. Padua was the place of his choice. He immediately made his mark there, and was himself appointed professor when only twenty-four years of age. He established a scientific tradition at Padua which that University has retained to this day.

No sooner was Vesalius settled at Padua than he applied himself with unparalleled diligence to lecturing and research. Students crowded to hear him (Fig. 31). To aid them he issued, in 1538, a short guide to anatomy and physiology. An examination of this shows that his physiological views were still those of Galen and Aristotle. After its issue Vesalius found that Galen and Aristotle were by no means always to be trusted. The realization of this led him constantly to doubt any statement by them. His scepticism was sometimes excessive, but it led him to put every statement made by his predecessors to the test of experience. This gives his later work an epoch-making value.

During the next four years Vesalius had ampler opportunities to dissect than he had yet encountered. He devoted a fiery energy to the preparation of his

Description of Fig. 31.

It shows a dissection scene at Padua. In the centre stands Vesalius dissecting a female body. At the head of the table stands an articulated skeleton. At its foot are dissecting instruments. Eager students throng around. In the foreground attendants are squabbling. On one side an attendant holds a monkey, one on the other a dog, for Vesalius had often to resort to animal in lieu of human anatomy. Shut off by a bar are members of the lay public. Gallants, grey-bearded scholars, monks, and an enthusiastic bookworm may be discerned among them. Other observers crowd in from every vantage point, even from the windows in the roof. The naked man to the left has been used by Vesalius to demonstrate the surface markings of the underlying organs. The whole scene is busy and vigorous in the extreme. It should be contrasted with the academic calm of Fig. 28 drawn fifty years earlier.

FIG. 31. TITLE-PAGE of the work *On the Fabric of the Human Body*, by Vesalius, published in 1543. See note opposite.

great work. *The Fabric* (that is 'workings', compare German 'Fabrik') *of the Human Body* was printed in 1543, a magnificent and beautifully illustrated volume. It is a landmark in the History of Science, and a wonderfully full record of a prodigious number of accurately recorded discoveries and investigations made by a single observer.

The masterpiece of Vesalius is not only the foundation of modern Medicine as a science, but the first great positive achievement of Science itself in modern times. As such it ranks with another work that appeared in the same year, the treatise of Nicholas Copernicus, *On the Revolutions of the Celestial Spheres*. The work of Copernicus removed the Earth from the centre of the Universe; that of Vesalius revealed the real structure of man's body. Between the two they destroyed for ever the medieval theories on the subjects of which they treat. But the work of Copernicus is one of close and subtle reasoning, still retaining many medieval elements, and is hardly a great exposition of what we now call the 'Experimental Method'. The work of Vesalius far more nearly resembles a modern scientific monograph than does the treatise of Copernicus.

The achievement of Vesalius was very well received by the scientific world. Nevertheless, soon after its publication, Vesalius resigned his professorship to take up the position of a court physician to the Emperor Charles V, the great monarch of the age. He was then only twenty-nine years old, but his scientific career was closed.

The edition of the *Fabric* was soon exhausted, and

the demand for more copies was met by imitations of the work by other hands. At last, in 1555, Vesalius was induced to issue a second edition. This contains certain changes in point of view that are important for the subsequent development of physiology. Vesalius now no longer merely hints his doubts as to the character of Galen's physiology; he openly asserts that he is unable to verify its fundamental bases.

We may take a single instance of this new outspokenness. In his description of the septum of the heart, he had written in the first edition:

'The septum of the ventricles of the heart is very dense. It abounds with pits on both sides. Of these pits none, so far as the senses can perceive, penetrate from the right to the left ventricle. We are thus forced to wonder at the art of the Creator, by which the blood passes from right to left ventricle through pores which elude the sight.' (Compare Fig. 21, p. 59.)

This passage is altered to something quite different in the second edition, where he writes:

'Although sometimes these pits are conspicuous, yet none, so far as the senses can perceive, passes from the right to the left ventricle. I have not come across even the most hidden channels by which the septum of the ventricles is pierced. Yet such channels are described by teachers of Anatomy, who have absolutely decided that the blood is taken from the right to the left ventricle. I, however, am in great doubt as to the action of the heart in this part.'

He further sets forth his whole policy with reference to Galen's view in the following interesting passage:

'In considering the structure of the heart and the use of its parts, I bring my words for the most part into agreement with the teachings of Galen; not because I think these on every point in harmony with the truth, but because, in referring at times to

new uses and purposes for the parts, I still distrust myself. Not long ago I would not have dared to diverge a hair's breadth from Galen's opinion. But the septum is as thick, dense and compact as the rest of the heart. I do not, therefore, see how even the smallest particle can be transferred from the right to the left ventricle through it. When these and other facts are considered, many doubtful matters arise concerning the blood-vessels.'

The work terminates with a little chapter *On the dissection of living animals*. We note that this, while dealing skilfully with the methods of physiological experiment, does not exhibit any very marked advance on the views of Galen.

Among the experiments on living animals that Vesalius enumerates are excision of the spleen, the loss of which he showed was consistent with life; and the cutting of the nerves that supply the organ of voice, with resultant loss of that faculty. He demonstrated that longitudinal section of a muscle interferes little with its function, but cross section produces disability in proportion to the injury. Such experiments had been performed by Galen, who had also reached the same conclusion as Vesalius, that it is through the spinal cord that the brain acts on the various muscles of the limbs and trunk. Vesalius repeated Galen's experiments on section of the spinal cord (p. 58). The most striking of his experiments

Description of Fig. 32.

It is beautifully and dramatically posed, and the drawing is remarkably accurate. The figure leans against a tomb, contemplating a skull. In the front left-hand corner of the top of the tomb is a part of the bony structure which supports the organ of voice (H).

The inscription on the tomb may be translated 'Man's spirit lives. The rest is Death's portion'.

The inscription at the top may be translated: 'A delineation from the side of the bones of the human body, freed from the other structures which they support and placed in their correct positions.'

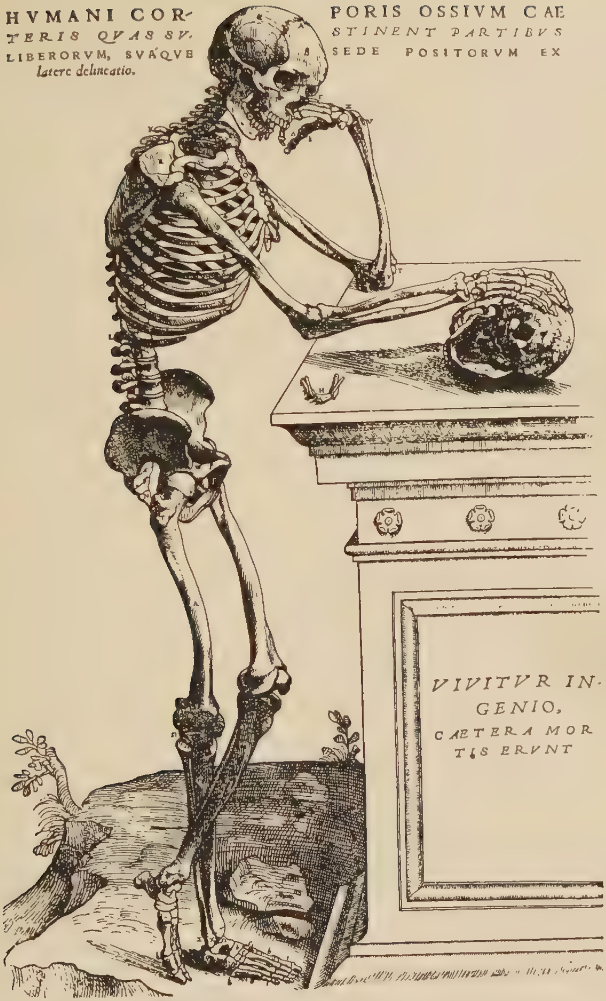


FIG. 32. SKELETON from the anatomical work of Vesalius, 1543. See note opposite.

were those on respiration. Here he showed that, even though the chest-wall be pierced, the animal may be kept alive if the lungs are continuously aerated by means of a bellows, and that a flagging heart may be revived by similar means.

The work of Vesalius at once placed the knowledge of the human body in a new position. It cannot be said that he completed the task of describing the naked-eye structure of the human body. Yet he went so far towards this that no dramatic improvement has since been made upon his methods. It is a fair statement that the whole of modern Descriptive Anatomy may be treated as a comment and correction and amplification of Vesalius. His work moreover stimulated a host of investigators.

§ 2. *The Anatomical Reaction on Surgery.*

The immediate effect of the new knowledge of Anatomy was an improvement in Surgery. The Wars of Religion of the sixteenth and seventeenth centuries were fierce and prolonged, and the army surgeons of the time had much experience of the treatment of wounds. The most prominent of the military practitioners was the Frenchman, Ambroise Paré (1517–90). He perceived the importance of anatomical knowledge and adapted his discoveries to the needs of Surgery. Paré did much to elevate the surgeon's profession from a despised handicraft to a position equal to that of other branches of the healing art.

Apart from the introduction of anatomical discipline into Surgery, Paré's four contributions to the surgical art were, firstly, his discovery that gunshot wounds are

not 'poisonous' as had theretofore been thought, and that therefore they do not require the application of boiling oil, but are best healed by soothing applications; secondly, the cognate doctrine that bleeding after amputations should be arrested, not by the terrible

FIG. 33. ARTIFICIAL ARMS AND HANDS, designed and figured by Ambroise Paré, and used by him for wounded soldiers from about 1560 onwards.

method of indiscriminate use of the red-hot cautery, but by simple ligature; thirdly, his advocacy of the method of turning the child in its mother's womb before delivery in certain abnormal cases; and fourthly, his ingenious devising of artificial limbs (Fig. 33). None of these four was without precedent. Nevertheless, the eminence, skill, and wide experience of Paré

were the main factor in the spread of these practices. But the greatest of all Paré's contributions to surgery was the service of his own personality, the example of his steadfast efforts to increase his knowledge of human anatomy and his skill in the art, and his constant emphasis on the surgeon's duty to exert his utmost efforts to avoid or relieve the patient's suffering.

In a famous passage Paré describes how he, a 'fresh-water soldier', on his first campaign, watched the other surgeons following the old rule of treating all gunshot wounds with boiling oil. At first he formed his practice on theirs. The theory was that gunshot wounds contained a poison, which the boiling oil was believed to drive out. Paré tells of his agitation when one evening, his supplies having run out, men had to be treated without the boiling oil. Next morning he was astonished to find that every man whose wounds had been treated only with a salve had rested fairly comfortably, while all who had undergone the customary treatment were, as we may well believe, in great pain. 'Then I resolved within myself never so cruelly to burn poor wounded men.' Another saying of the shrewd old surgeon is the famous adage 'I dressed him and God cured him'.

Paré's works were frequently reprinted and translated into various European languages, including English. They exercised the widest influence on surgical craft in the sixteenth and seventeenth centuries. Like Vesalius, he is an example and type of a large class. In every country surgeons arose who made an effort to utilize the new anatomical knowledge.

§ 3. *The Renaissance of Internal Medicine.*

Internal Medicine lagged behind Surgery at this period. The anatomical reforms of Vesalius were unaccompanied by any commensurate advance in physiological knowledge, and without a scientific Physiology there can be no science of Internal Medicine. The practice of the physicians thus remained in effect that of the Middle Ages. The ruling idea was still that of the 'four humors' corresponding to the four 'temperaments' (Fig. 13, p. 34, and compare Fig. 34, p. 97).

There are, however, three respects in which we see an improvement of the physician's art during the sixteenth and first half of the seventeenth century.

Firstly, there was some improvement in the medical texts that were habitually read. More reliable translations were now available. Notably the great Hippocratic works became more widely disseminated. They formed a substitute for the old texts translated or mistranslated from the Arabic.

Secondly, the extension of geographical knowledge and the formation of settlements and colonies brought new drugs upon the market. These were often a mixed blessing, for some of the drugs were useless and others dangerous. Nevertheless, to this process Medicine owes several important contributions, among them Ipecacuanha, Cinchona (p. 326), and, by no means least, Tobacco (Fig. 35). Apart from the amenities introduced by Tobacco, it was for long of great value as a narcotic drug. Moreover, there was a corresponding advance in Botany. The movement was cursed with the 'practical' spirit, and only those plants thought to

have an application as drugs were exactly figured and described. Nevertheless, the beautifully illustrated herbals of the sixteenth and seventeenth centuries exercised, by the care and accuracy of their execution, an exemplary influence on the development of Biological Science in general and of Medical Science in particular.

Thirdly, there was some advance in the knowledge of the natural history of infectious disease. A rational theory of the nature of infection was placed before the public as early as 1546 by the Veronese physician, Girolamo Fracastoro (1483–1553). He regarded infection as due to the passage of minute bodies from the infector to the infected. These hypothetical minute bodies had the power of self-multiplication. The conception bore a superficial resemblance to the modern germ theory of disease. An important contribution to the conception of epidemics was also made by the French physician Guillaume de Baillou (1538–1616), who reintroduced the old Hippocratic idea of 'Epidemic Constitution', i.e. that particular seasons and particular years are of their nature subject to particular diseases. The idea was extended and developed by the English physician Thomas Sydenham (1624–89), and it still has its value.

In connexion with their epidemiological work these three men, Fracastoro, de Baillou, and Sydenham, made significant additions to the knowledge of particular infectious conditions. Thus, during the sixteenth and seventeenth centuries there arose an exact body of teaching concerning acute infectious diseases which was the necessary prelude to the introduction of more effec-

FIG. 34. FIGURE ILLUSTRATING THE 'FOUR TEMPERAMENTS', from the Guild Book of the Barber-Surgeons of York, now in the British Museum. The figure was prepared about 1500. Above, to the left, is the *Melancholy* man, and to the right the *Sanguine*. Below to the left is the *Choleric* man, and to the right the *Phlegmatic*. On the scroll work is written in English 'Ther ar the iiij umors, thath ar oderwysse calde the iiij complecconis thath ar resceuid un to the iiij elementis, Hafyng the kynd of humors', which may be rendered 'There are the 4 humours, that are otherwise called the 4 complexions, that are received unto the 4 elements, having the nature of humours'. For the theory compare Fig. 13, p. 34.

tive preventive measures at a later date. To one infectious disease we may refer more particularly.

During the Middle Ages there had smouldered in various districts an obscure disease, sometimes more or less dimly distinguished under various specific names, but most frequently confused with Leprosy. Towards the end of the fifteenth century this disease, which was still imperfectly distinguished in men's minds from Leprosy, broke out in epidemic and virulent form all over Europe. It caused great destruction of life and developed everywhere as a problem of national importance. Various titles were given it, such as 'pox', 'the French disease', 'the Spanish disorder'. Only tardily was it recognized that the disease was usually of venereal origin. Not till 1530, on the suggestion of Fracastoro, did it receive its modern cognomen *Syphilis*. From the time of its recognition, Syphilis has been pursued by a portentous mass of literature, the mere sifting and verification of which is a formidable task. Alarm, misunderstanding, religious feeling, false modesty, wilful misrepresentation, and change in type of the disease itself have all contributed their quota of obscurantism and fable to a naturally difficult subject (Figs. 35 and 36). Fracastoro did something to bring order out of the confusion. To him also we owe the first good scientific descriptions of several other destructive diseases, among which Typhus fever, now known to be conveyed by lice (p. 258), takes a prominent place.

De Baillou (1538–1616) first described Whooping Cough, and was the first to use the word *Rheumatism* in the modern sense. He was moreover the first, since Hippocrates, to distinguish between Rheumatism and

Gout. De Baillou's works deeply influenced Sydenham, who held very similar epidemiological views, and uses a somewhat similar vocabulary (p. 100).

We have seen how the knowledge of Anatomy for-

FIG. 35. THE EARLIEST PICTURE showing the use of Tobacco. From a work on Brazil, printed in Paris in 1558. In the centre of a native hut stands an Indian suffering from Syphilis. Behind him, on the left, a man smokes a huge cigar over him as a curative measure. Right and left his arms are held by two figures who seek to suck the poison out of him. Another offers him a curative plant. Behind him is a 'hammock'—the word is of American-Indian origin and means 'tobacco-bed'. Above his head are a monkey, a parrot, and a bale of tobacco.

warded Surgery, while, with the lag in Physiology, Internal Medicine remained in a backward state. It is well to recall however that a knowledge of Anatomy and Physiology will not, of themselves, make a man a

scientific physician. The object which presents itself to a physician is neither a living anatomy nor a physiological model. It is a sick and suffering patient. The physician's first task is to examine exactly the phenomena of sickness and suffering, and in doing this the first demand on his knowledge will be the history and fate of others who have endured like sickness and suffering. When he has ranged these instances in his mind he may turn, for explanation and relief, to the resources suggested by other sciences, Anatomy and Physiology among them. But all the Anatomy and Physiology in the world will not aid the practitioner who is unacquainted with the natural history of disease. This is the truth that was firmly seized by Thomas Sydenham.

The Natural History of Disease was a subject which Sydenham pursued with lifelong devotion. Before his time the phenomena of disease had been classified, subdivided, discussed, and treated with all the subtlety and skill of scholastic thought. Men had now and again shaken themselves free from the shackles of the medieval system, and had here and there corrected the views of Galen or amplified the limited achievements of their predecessors. Yet none before Sydenham had set himself to consider all the actual cases of disease that lay before him as a subject of scientific description and analysis. That was the great achievement of the 'English Hippocrates'. We should not find it easy to point to any important discovery to associate with his name. But he did more than discover. He initiated a new mode of approach. He was the founder of modern Clinical Medicine.

In 1666 Thomas Sydenham published his classic work, *The Method of Treating Fevers*, dedicated to his friend Robert Boyle, 'the Father of Chemistry' (pp. 124–5). The book opens with the almost Hippocratic phrase

FIG. 36. Allegorical picture illustrating the venereal plague Syphilis.

From a work printed in Germany in 1496. The Virgin sits enthroned on clouds, crowning a crusader, who kneels at her right hand. The Holy Child on her knee sends forth the plague of Syphilis as a scourge on mankind. Two women, spotted with the rash of the disease, kneel in supplication before her on her left. In the foreground of the picture lies a corpse dead of the disease, the speckled ravages of which may be seen upon it.

'A disease, in my opinion, how prejudicial soever its causes may be to the body, is no more than a vigorous effort of Nature to throw off the morbific matter, and thus recover the patient'. We have here the *healing*

power of Nature of Hippocrates (p. 21), which had been obscured and overlaid in the twenty centuries which lay between the two great physicians. The works of Sydenham may reasonably be regarded as the first great commentary on the Hippocratic theme. Sydenham set well on its way the conception of infectious conditions as specific entities, a conception which has since been illuminated by the germ theory of disease (p. 224 ff.).

§ 4. *The First Physical Synthesis.*

Manifestations of the Human Spirit are not accustomed to confine themselves exactly within the convenient limits of the centuries. Nevertheless, it happens that in the History of Science the year 1600 does, in fact, correspond to something of the character of a real change in the current attitude to Nature. That year really ushers in the era of physical experiment. The last of the great transitional thinkers who mark the waning of Renaissance philosophy was Giordano Bruno, the martyr of science.

Giordano Bruno (1548–1600), who was no practical scientist, had eagerly incorporated into his often fantastic philosophy the ill-worked-out conclusions of Copernicus (p. 88). Nominally adopting the Copernican theory, he modified it fundamentally. Copernicus, having placed the Sun at the centre of the World, and made the Earth and other planets circle round it, had still left the stars at a fixed and definite distance, as had the ancient astronomers. The limitation of the sphere of the fixed stars was obnoxious to Giordano, and he removed the boundaries of the Universe to an

infinite distance, in accordance with the principles of his philosophy. The change may seem unimportant save for astronomy, but, in fact, it came to influence every department of scientific thought, for the endlessness of Nature is implicit in the modern scientific attitude.

Giordano was burned at the stake at Rome, after seven years' imprisonment, in 1600. In the same year the experimental era was ushered in with the work of William Gilbert (1544–1603), *On the Magnet*, in which he not only demonstrates experimentally the properties of magnets but also shows that the Earth itself is a magnet. In the same year, too, Tycho Brahé (1546–1601) handed over the torch to Johannes Kepler. Tycho was the last of the older astronomers who worked on the Aristotelian view of circular and uniform movements of heavenly bodies. Kepler was the real founder of the modern astronomical system. The period from 1600 onward lies with new men, Galileo (1564–1642) and Kepler (1571–1630) among astronomers and physicists, Harvey (1578–1657) among biologists, Descartes (1596–1650) among philosophers.

The seventeenth century opened with an extraordinary wealth of scientific discovery. As we glance at the mass of fundamental work produced during that period, we perceive the major departments of Science, as we know them to-day, becoming clearly differentiated. The acceptance of Observation and Experiment as the only method of eliciting the Laws of Nature reaches an ever-widening circle. Even to enumerate the names of the seventeenth-century pioneers would be a formidable task. The sciences penetrated to the Universities and influenced the curricula. The number

of scientific men became so large and so influential that separate organizations were formed by them in the interests of their studies. It is the age of the foundation of the 'Academies', of which the English Royal Society is a type.

From the multitude of workers on these subjects we can but select a few names. In the first half of the century Galileo and Kepler are the main exponents of natural law. Descartes takes his place here as the first since antiquity who sought to explain the phenomenal universe on a unitary basis. In the second half of the period comes the mighty figure of Newton, whose researches ushered in that phase in our story in which we live to-day.

The early training of Galileo Galilei had been scholastic and Aristotelian. By 1590, however, he had begun to doubt, and was making experiments on the rate of acceleration of falling bodies. His conclusions were demonstrated in 1591 from the leaning tower of Pisa. By that famous experiment he showed, in the most public manner, the error of the Aristotelian view that the rate of fall was a function not of the weight of the object but of the period of fall. Revolutionary also was Galileo's work of 1604. In that year a new star appeared in the constellation *Serpentarius*. He demonstrated that this star was situated beyond the planets and among the remote heavenly bodies. Now this remote region was regarded in the Aristotelian scheme as absolutely changeless. Although new stars had been previously noticed, they had been considered to belong to the lower and less perfect regions nearer to earth. To the same lower region, according to the then

current theory, belonged such temporary and rapidly changing bodies as meteors and comets. But Galileo had attacked the incorruptible and unchangeable heavens.

In 1609 Galileo made accessible two instruments that were to have a deep influence on the subsequent development of Science, the Telescope and Microscope. It is with the former instrument that his name is most frequently associated. His first discoveries made by means of the Telescope were issued in 1610. That year was crowded with important observations especially on the inner planets and notably on Venus. It had been rightly claimed in criticizing the Copernican hypothesis that, if the planets resemble the Earth in revolving round the Sun, only such parts of them should be luminous as are exposed to the Sun's rays. In other words, they should exhibit phases like the Moon. Such phases in Venus were now actually observed by Galileo. In the following year he described sunspots and traced them round the Sun's disk.

We need not follow the further astronomical observations of Galileo, nor need we discuss the contest with the older school on which he embarked. It is sufficient to remind ourselves that the appearance of a new star, the behaviour of the rings of Saturn, the observations of the phases of Venus and of the Sun's spots, struck a blow at the Aristotelian astronomy comparable to that delivered against the Aristotelian physics by the falling weights from the leaning tower of Pisa. Aristotelian astronomy demanded heavens eternally changeless. Here were changes and new appearances in the heavens, clearly visible to all who would see.

During these years too, Galileo was laying firm the foundations of the science of Mechanics. Out of his mechanical researches came a new way of looking at the objects of Nature which has profoundly influenced the entire subsequent course of science. That way is best expressed in Galileo's own words, which place him among the philosophers whose thought influences all those who deal with scientific themes.

'As soon as I form a conception of a material or corporeal substance, I simultaneously feel the necessity of conceiving that it has boundaries and is of some shape or other; that relatively to others it is great or small; that it is in this or that place, in this or that time; that it is in motion or at rest; that it touches, or does not touch, another body; that it is unique, rare, or common; nor can I, by any act of imagination, disjoin it from these qualities. But I do not find myself absolutely compelled to apprehend it as necessarily accompanied by such conditions as that it must be white or red, bitter or sweet, sonorous or silent, smelling sweetly or disagreeably; and if the senses had not pointed out these qualities language and imagination alone could never have arrived at them. Therefore I think that these tastes, smells, colours, &c., with regard to the object in which they appear to reside, are nothing more than mere names. They exist only in the sensitive body, for when the living creature is removed all these qualities are carried off and annihilated, although we have imposed particular names upon them, and would fain persuade ourselves that they truly and in fact exist. I do not believe that there exists anything in external bodies for exciting tastes, smells and sounds, &c., except size, shape, quantity, and motion. If ears, tongues, and noses were removed, I am of opinion that shape, quantity, and motion would remain, but there would be an end of smells, tastes, and sounds, which abstractedly from the living creature I take to be mere words.'

This passage is a veritable Charter of Science. From Galileo's day to ours, men of science have occupied

themselves in measuring size, shape, quantity, and motion, the 'primary qualities', and expressing their knowledge in that measured form. They have rele-

FIG. 37. SANCTORIUS IN HIS BALANCE. Sanctorius was able to eat and even to sleep in his balance, counterpoised by a weight working on the principle of the steelyard. He was thus able to test his weight under various conditions, and notably to estimate the amount of the 'insensible' perspiration. His were the first experiments on 'Metabolism' (see p. 108).

gated colours, smells, tastes, sounds, and other sense-impressions to the position of 'secondary qualities', and have tried to express them, when they express them at

all, in terms of the primary qualities. We need not enter on the philosophical discussion as to how far the primary qualities are in truth more real than the secondary, but it is a fact that, since the time of Galileo, Science has come to be regarded more and more widely as an exact process. *Science is Measurement.* It is a conception that has affected the medical no less than the other sciences, and it is a conception that Medicine, for good or ill, owes to Galileo.

§ 5. *The Revival of Physiology.*

The first to apply Galilean principles of measurement to biological matters was Sanctorius (1561–1636), a professor at Padua. He described a thermometer for use in taking the temperature of the human body (Figs. 39 and 40), and an apparatus for comparing the rate of pulse beats (Fig. 41). Both these he modified from devices suggested by Galileo (Fig. 38). It is an indication of the transitional character of the Science of the time that he describes these instruments in a commentary on a medieval translation of the *Canon* of Avicenna (p. 67). He also sought to compare the weight of the body at different times and in different circumstances. In the process of doing this, he demonstrated that the body loses weight by mere exposure, a process which he ascribed to 'insensible perspiration' (Fig. 37). By these experiments he laid the foundation of the modern study of 'Metabolism' (p. 220).

While Sanctorius was engaged in this pioneer work at Padua, the movement that Vesalius had inaugurated there was making further conquests in the purely biological line. Vesalius had been succeeded at Padua by

a series of anatomists of great eminence. Perhaps the most prominent among these was Jerome Fabricius

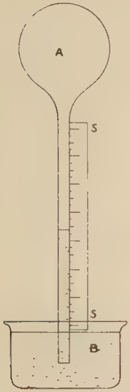


FIG. 38

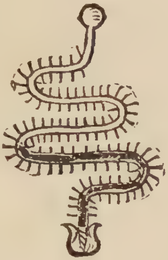


FIG. 39

FIG. 40

FIG. 41

FIG. 38. The principle of Galileo's thermometer. A tube ending in a bulb A is inverted over a mercury bath B. If the temperature fall the air in A will contract and mercury be drawn up into the tube. If the temperature rise the air in A will expand and mercury be driven out of the tube. The height of the mercury can be read on the scale SS. The reading will not be accurate because the instrument is, in fact, also a barometer, since the mercury in B is exposed to the atmospheric pressure, which will therefore affect the rise in the tube.

FIG. 39. The application of the same system by Sanctorius who used a curved tube.

FIG. 40 is not, as might be thought, a man trying to swallow a centipede, but the adaptation of the instrument of Sanctorius as a clinical thermometer.

FIG. 41. Galileo's simple and effective 'pulsimeter'. It consists only of a weight suspended on a thread. This thread is held in the hand and the weight made to oscillate as a pendulum. As the thread is shortened the oscillations increase in frequency. The process is continued until the pendulum oscillates to time with the pulse. The length of the free thread is then read off on the accompanying scale. It was used by Sanctorius.

(1537–1619), usually called 'of Aquapendente', after the small Tuscan village where he was born. This

Fabricius of Aquapendente taught at Padua for over fifty years, from 1565 till his death at eighty-two in 1619. He made many contributions to the advancement of anatomy, most of which had physiological bearings. Thus, he was the effective founder of modern embryology and the author of the first illustrated work on that subject, in which he describes the formation of the chick in the egg. He was the first to give accurate figures of the structure of the eye. He developed the mechanics of muscular motion. He added to his qualities as an observer the power of attracting younger men.

In spite of all his powers, however, Fabricius never shook himself free from ancient views, and especially he was steeped in the theories of Aristotle and Galen. This backward-looking habit prevented his work from being as important as it might otherwise have been. In connexion with the circulation, for instance, he made a striking discovery, but wholly failed to draw out its most important lesson.

In 1600 he published his book, *On the Valves of the Veins*. In it he says that these structures are so placed that their mouths are always directed *toward* the heart (Fig. 42), yet he never gets an inkling that the effect of these valves must be to prevent blood flowing into the veins except toward the heart. He is too set on the old Galenic physiology to permit such a revolutionary thought. The real importance of Fabricius is, therefore, not so much as an investigator but rather as a teacher, a capacity in which he shone above all other physiologists for generations to come. He would deserve our remembrance if only as the master of the discoverer of the circulation of the blood, William Harvey.

The Englishman, William Harvey (1578–1657), after education at Cambridge, went to Padua in 1599, when Fabricius was at the height of his powers. Returning to England in 1602, he set up in practice in London. During the years which followed, he was dissecting and experimenting very industriously, and by 1615 had reached a clear conception of the circula-

FIG. 42. DISSECTION OF A VEIN in the thigh and leg from a work *On the Valves of the Veins*, published by Fabricius in 1603 at Padua. These valves prevent the passage of the blood in any direction except toward the heart. They may be seen at the points P, Q, R, S, and T.

tion of the blood (Fig. 43), though he did not publish his discovery till some thirteen years later.

To discuss the actual steps by which Harvey made his discovery would be beyond our scope. He had, however, been well trained in experimenting on living animals by Fabricius, and had read widely in anatomical literature. He was of a contemplative turn of mind and his quiet and cautious temper, united with his enthusiasm and skill as an experimenter, provided a superb mental equipment for a life of scientific investigation.

Harvey, early in his work, reached two fundamental conceptions concerning the vascular system. He perceived that the valves in the veins would permit the blood to pass only towards the heart (Fig. 43), while those in the great arteries arising from the heart would permit the blood to pass only away from the heart. In connexion with the movement of the blood, Harvey's crucial point is that it must be *continuous*, and *always in one direction*. This really clinches the matter, for consider the capacity of the heart. Let us suppose that either ventricle holds but 2 ounces of blood. The pulse beats 72 times a minute and 72×60 times an hour. In the course of one hour, therefore, the left ventricle will throw into the aorta, or the right ventricle into the pulmonary artery, no less than $72 \times 60 \times 2 = 8{,}640$ ounces $=$ 38 stones 8 lb. In other words, in one hour the ventricle will throw into the great artery more than three times the body weight of a heavy man. Where can all this blood come from? Whither can it all go? It cannot come from the ingested food and drink, for no one could consume so much in one hour! It cannot reach and remain in the tissues, for they would soon all burst and ooze with blood! The solution of the puzzle, Harvey came to see, is that it is the same blood that is always being pumped into the arteries, and the same blood that is always coming back through the veins. In other words the blood *circulates*, a fact which Harvey proceeded to demonstrate with convincing thoroughness (Fig. 43).

We may note that, though Harvey demonstrated the existence of the circulation, he was never able to follow it throughout, for he did not see the capillary

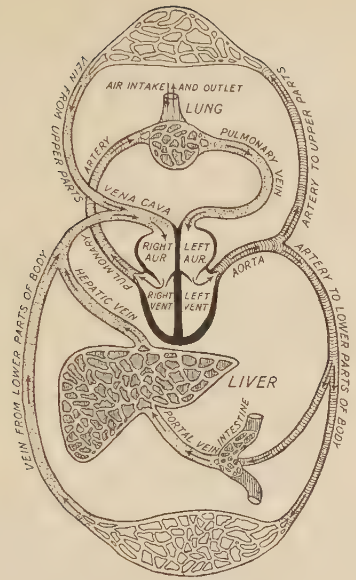


FIG. 43. DIAGRAM TO ILLUSTRATE THE NATURE OF THE CIRCULATION OF THE BLOOD. Leaving the *left ventricle*, when the walls of that cavity contract, the blood is forced through the valves into the great artery known as the *aorta*. From the aorta it passes into smaller and ever smaller arteries, finally reaching the *systemic capillaries* or the *portal capillaries*. After travelling through one or other capillary network it enters a vein. Thence it passes into larger and ever larger veins, until it ultimately enters the great vein known as the *vena cava* that opens into the *right auricle*. It has now completed the Greater Circulation. As the right auricle contracts the blood passes through the valves between the right auricle and right ventricle into the *right ventricle*. From there it enters the Lesser Circulation, passing into the great *pulmonary artery*, which conducts it to the lung. In the lung the pulmonary artery breaks up into branches and finally into capillaries. Through these the blood travels until it reaches a tributary of the *pulmonary vein* and finally the pulmonary vein itself. The pulmonary vein empties its blood into the *left auricle*. From the left auricle the blood passes at last into the left ventricle from which it started, having traversed both the Greater and the Lesser Circulations.

To understand the change which Harvey wrought in the conception of the workings of the body, this description and diagram should be compared with the description and diagram on pages 56–59.

vessels by which the blood is conveyed from the terminal branches of the arteries to the smallest tributaries of the veins. These were first demonstrated by Malpighi (p. 116).

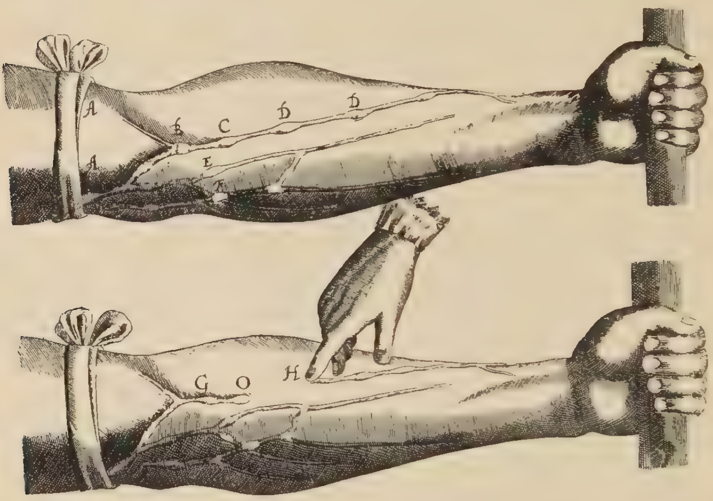


FIG. 44. THE VALVES in the superficial veins as seen in the bandaged arms of living men, from William Harvey's great work on the *Circulation of the Blood*, printed in 1628. The bandage is seen on the upper arm in each case, and the valves are indicated, as in life, by nodes or swellings in the veins. If a finger is pressed along the vein from one valve to another as from node O to node H in a direction away from the heart, the vein from O to H will be emptied of blood. It will remain empty, since the valve at O does not permit the passage of blood away from the heart, but only towards it. This observation was Harvey's starting point for his great discovery.

The knowledge of the circulation of the blood has been the basis of the whole of modern Physiology and with it of the whole of modern rational Medicine. The attitude of Galen and Aristotle towards the heart and the great vessels passed into the shadow. The blood, it was seen, is a carrier always going round and round

on the same beat. What it carries, and why, how and where it takes up its loads, and how, where, and why it parts with them, these are questions the answering of which has been the main task of Physiology in the centuries that have followed. As each of the questions has obtained a more and more rational answer, so clinical Medicine has always made a step forward, and has come to approach more nearly to a true science. Thus it is that the work of Harvey lies at the back of almost every important medical advance.

§ 6. *Microscopic Analysis of the Animal Body.*

The compound microscope was first made into an effective instrument by Galileo. It was, as it were, a *by-product* of his invention of the telescope. With that instrument he had seen enough to convince himself that the movement of the Sun round the Earth was but an appearance. At the very time that Harvey was giving his first course of lectures securely in London, Galileo's teaching was attracting the unwelcome attention of the Inquisition in Rome.

Galileo's microscopes, however, were far less satisfactory than his telescopes. For optical reasons which we need not discuss, these early compound microscopes failed to give a clear picture. With any high degree of magnification, the image was always blurred and distorted. More than three centuries were to pass before a better compound system was introduced. But about 1650 a way was found of constructing and mounting simple lenses of very high power. Many of the most important microscopical discoveries of the second half of the seventeenth century were, therefore, made with

a simple lens. This was notably the case with much of the work of the great investigators Malpighi and Leeuwenhoek (Fig. 49 A).

Marcello Malpighi (1628–94) was born in the year in which Harvey's work was published. He became

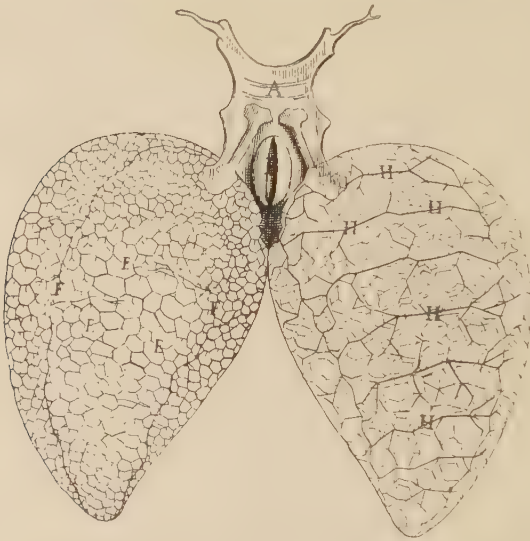
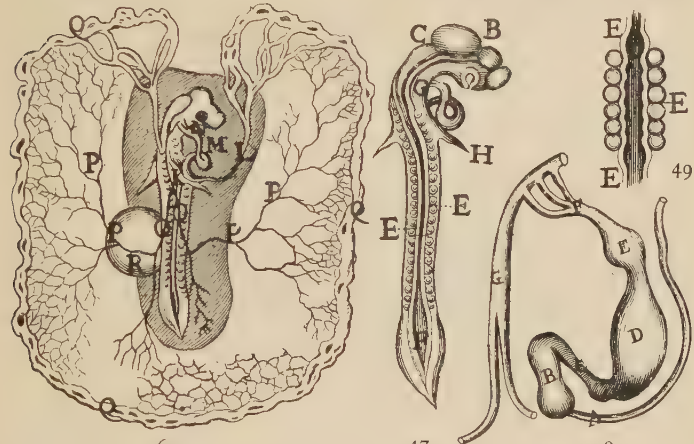


FIG. 45. LUNGS OF FROG, showing the capillary vessels from a figure by Malpighi in the rare first edition of his work *On the Lungs*, published at Bologna in 1661. A is the part of the larynx, B is the opening of the larynx into the trachea or air-tube leading to the lung. The letters EEE represent the outer surface of the lung and exhibit the network of capillary vessels. On the other side the sack-like lung has been laid open, and is viewed from the inside. The letters HHH are placed upon veins on the inner surface of the lung. These arise from capillaries which are indicated between the veins.

a professor at Bologna, having early developed great skill in minute investigation. His first work, which appeared in 1661, supplied the element missing in the investigations of Harvey, for he describes the actual passage of blood from the arteries to the veins through

the 'capillary' blood-vessels (Fig. 45). Harvey, who did not use a microscope, knew nothing of the capillaries.



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In 1673 Malpighi published in London his work *On the Formation of the Chick in the Egg*. Thirteen years later, in 1686, he published extensions and corrections of this work. Our figures are taken from the later work.

FIG. 46 is the whole embryonic area, at about the end of the second day of incubation. The embryo itself is seen with its large head containing the three 'cerebral vesicles' (which are the rudiments of the brain), the large eye, the protuberant coiled heart (NM), from which vessels pass to the 'vascular area'. The segmented vertebral column is well seen, as well as the vessels forming a network as they meander over the vascular area.

FIG. 47 exhibits the embryo more enlarged and in greater detail.

FIG. 48 is an enlarged figure of the heart; the part D will ultimately form the ventricle, B the auricle, and A the vena cava. At F the aorta sends forth three branches which unite again. The nature of these branches was not understood in Malpighi's time. They have been explained in modern times by embryologists working under the inspiration of evolutionary theory as having once furnished the blood supply to the gills of a fish-like ancestor.

FIG. 49 is a part of the segmented vertebral column still more enlarged.

The object which yielded up the secret was the lung of the frog. This organ in the frog happens to be almost

transparent, is very simple in structure, and is furnished on its surface with particularly conspicuous capillary vessels. Malpighi could hardly have selected an object better suited for this particular research. This important discovery of his drew the attention of scientific men in England. The Royal Society soon entered into correspondence with him, and during the remainder

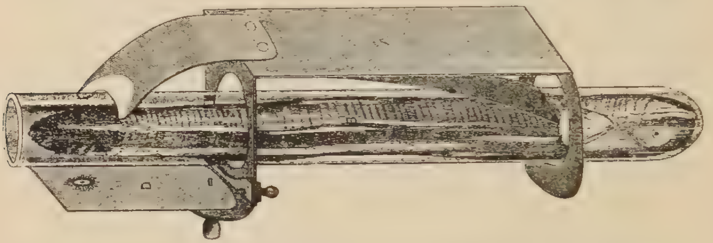

FIG. 49A. ONE OF LEEUWENHOEK'S MICROSCOPES. To understand the figure turn the book at right angles to the line of print. The object to be examined—here the tail of a small eel—is placed in water in the test-tube B. This test-tube is held firmly by two springs in the frame A. The microscope itself is simply a flat metal plate D, into which is let a very minute lens, the setting of which is shown above the letter D (when the head of the eel is downwards). The lens is focused by means of a fine screw which moves the whole plate.

of his life undertook the publication of his researches.

The contributions of Malpighi to biological knowledge were very numerous and important. The study of early development, embryology as it is now called, was greatly extended by him. The later stages of embryological development had been investigated by Fabricius (p. 110) and some additions to the subject had been made by Harvey. Malpighi, applying his microscope to the earlier germ of the animal body, described in detail the development of the organs, notably of the heart and the nervous system (Figs. 46–49). He also demonstrated

the minute structure of the skin, spleen and liver, in all of which there are anatomical structures that still bear

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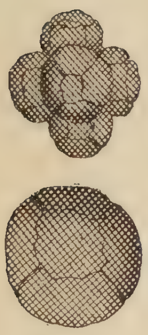

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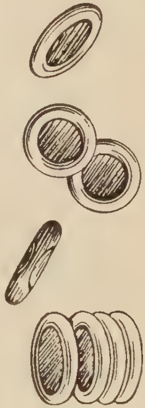

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FIGS. 50–53 illustrate the blood corpuscles and circulation after Leeuwenhoek.

FIG. 50. Oval blood corpuscles of salmon showing nuclei.

FIG. 51. Human red blood corpuscles.

FIG. 52. Drawing of human red blood corpuscles for comparison with Leeuwenhoek's figures.

FIG. 53. Capillary network in web of frog's foot. A, C and E are arterioles, B, D and F are venules.

his name. He investigated microscopically the structure and physiology of insects and plants, and his figures of the cell-walls of the latter are good and clear.

A most remarkable contemporary microscopist was the Dutchman, Anthony van Leeuwenhoek (1632–1723). Without medical or scientific training, desultory and secretive in his mode of working, he was withal an observer of genius and a very shrewd investigator. During his long and industrious life he

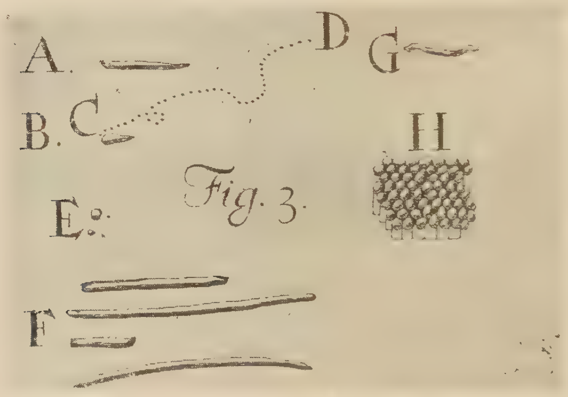
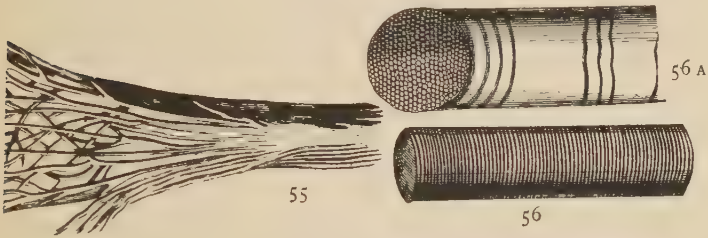


FIG. 54. THE FIRST REPRESENTATION OF BACTERIA. They were figured by Leeuwenhoek in the *Philosophical Transactions of the Royal Society* of London in 1683.

made a series of disconnected discoveries which for originality and importance have been surpassed by no other microscopic observer. He improved and extended the knowledge of the capillary circulation of which Malpighi was the discoverer (Fig. 53), he gave figures of the blood corpuscles (Figs. 50–1), of spermatozoa and of fibres of muscles (Figs. 55–7), and advanced the knowledge of embryology. He always worked with a simple microscope, using lenses of exceedingly short focal length (Fig. 49A). It is astounding that, with such

an instrument, he saw and figured bacteria as early as 1683 (Fig. 54).

The short life of a second Dutch microscopist of the seventeenth century, Jan Jacobz Swammerdam (1637–80), was abbreviated yet further, as regards scientific achievement, by his insanity. In his brief



FIGS. 55–56A. Drawings of the structure of muscle made about 1682 by Leeuwenhoek.

FIG. 55 shows a muscle teased up into bundles of fibres, magnified.

FIG. 56 is a more magnified view of a bundle of fibres. The cut fibres are shown at the end.

FIG. 56A is a very highly magnified view of a single fibre showing very clearly the striations that are very characteristic of voluntary muscle.

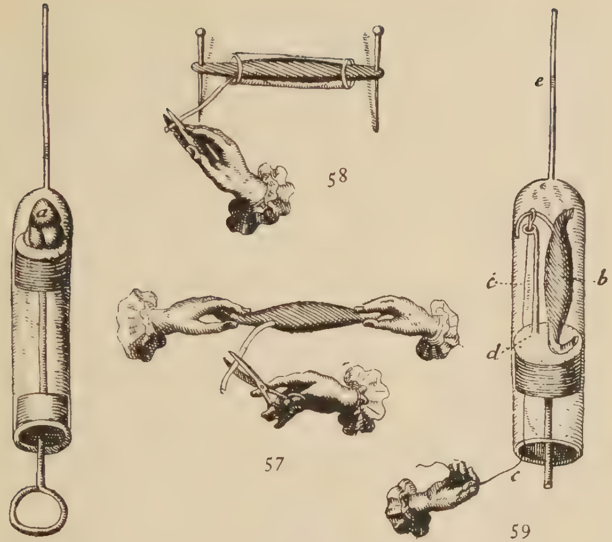
working period he produced his *Bible of Nature* which, alone of the scientific writings of his age, is still consulted by modern naturalists for the unique beauty and accuracy of its figures. He extended the knowledge of embryology and he made a series of physiological experiments which involved the very modern physiological device known as the 'nerve-muscle preparation'. He is thus the founder of an important department of Physiology. Swammerdam showed that, during contraction, a muscle does not increase in bulk, and that therefore the nerve brings nothing to it in the way of the hypothetical 'nervous fluid' in which many then believed (Fig. 63).

He applied the same reasoning to the heart (Figs. 57–60). Swammerdam was perhaps the first to see the blood corpuscles. Like several of his contemporaries and followers, he made injection preparations of much beauty and delicacy. His great work was not published till after his death. The copper plates that he had prepared for it were found and purchased by Boerhaave (p. 140), who produced them at his own expense.

These microscopists and several others in the seventeenth century did much to explore the minute structure of the animal body. Their revelations showed at once an unexpected complexity of all the parts, and an unexpected resemblance of some of those parts which appear diverse to the naked eye. Thus, the structure of the body came to be subjected to a process that we may call 'microscopic analysis'. For long after the time of these classical microscopists no effective improvements were made in the microscope, and the progress of microscopic analysis lay almost dormant. With the improvements in the microscope of the nineteenth century, the method was taken up again with triumphant results.

§ 7. *From Alchemy to Chemistry.*

During the sixteenth and the first part of the seventeenth century the basic science of Mechanics had been placed on a firm footing by Galileo. Astronomy, with Galileo and Kepler, had made the great break with the past. Anatomy and Physiology had put on their modern dress. Chemical knowledge, however, remained peculiarly backward. Many advances, it is true, had been made in technical processes, but investigations designed to throw light on theory were mostly



FIGS. 57–60. Experiments by Swammerdam to illustrate the nature of muscular contraction.

FIG. 57 is the simplest form of what physiologists call a 'nerve muscle preparation'. It is merely a living muscle dissected away from the body, but with its nerve still attached. In the experiment the two tendons of the muscle are held by the two hands. An assistant pinches the nerve with forceps. The muscle thereon contracts and draws the two hands together.

FIG. 58 shows the muscle passed through a glass tube. Its two tendons are fastened by two pins. When the nerve is pinched the pins are drawn towards each other, and the muscle, in contracting, fills the middle of the tube.

FIG. 59 shows the nerve-muscle preparation enclosed within a tube. This tube has a narrow neck in which, at *e*, is a drop of water. The other end of the tube is closed by a cork. The nerve may be squeezed by pulling the thread *c c*, which passes through the cork and drags the nerve into a narrow wire loop.

FIG. 60 is a similar experiment with the heart, which contracts and expands spontaneously and needs no irritation.

The experiments 59 and 60 show that during 'contraction' no new substance passes into the muscle, since it does not then increase in size. This gives the death-blow to the conception of a 'nervous fluid' passing into the muscle to cause contraction by distending it.

prosecuted by the band of dupes and charlatans who, since the Middle Ages, had been seeking the Philosopher's Stone. The old theory of the four elements, earth, air, fire, and water (p. 34), formed an ill basis for experiment. Some philosophers, it is true, had put forward crude atomic theories, but they had little experimental evidence to adduce. Nevertheless even the alchemists had made some advance and had, for instance, perfected a system of weighing.

The great defect of the ancient view of matter was that it contained no definite conception of the nature of a *pure* substance. Metals, for instance, were regarded, like other substances, as a mixture in certain proportions of the four elements of Aristotle (p. 34). Thus, the transmutation of one metal or one substance into another by distillation did not seem an absurdity, or even a task of special theoretical difficulty.

The main agent in changing the chemical outlook was Robert Boyle (1627–91). He was a member of a small association of scientific men, the *Invisible College*, which met first in London, then in Oxford, and finally in 1663 was incorporated by Royal Charter as the *Royal Society*. These men were satisfied that the only way to learn anything effective about Nature was by observation and experiment. From their discussions all purely speculative views were excluded. They agreed to meet together solely to compare experiences, to demonstrate experiments, and to draw immediate deductions. None of them was more active in these matters than Boyle.

The actual chemical and physical discoveries of Boyle were very numerous, but his great achievement,

the real service he rendered to learning in general and to medicine in particular, was his introduction of a new spirit into Chemistry. Under him that study was no longer prosecuted for purely practical ends; it was set

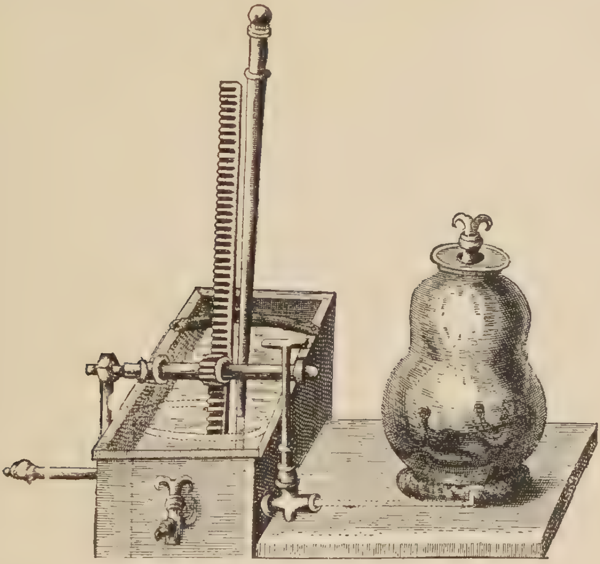


FIG. 61. ONE OF ROBERT BOYLE'S AIR PUMPS. A cat has been placed in the receiver. It shows signs of asphyxia as soon as the air is exhausted by the pump.

free from the mystic factor in Alchemy and it was loosed from the chains which bound it to Medicine, to the disadvantage of both. Chemistry thus became an independent science, the principles of which were to be ascertained by experiment, and its truths pursued for their own sake.

Boyle demonstrated that the air is a material substance and has weight. By means of his air-pump, he

proved clearly that this substance is necessary for the support of respiration (Fig. 63). The law of the compressibility of gases is still known by his name. Most important of all Boyle's contributions to chemical theory was his adumbration of the conception of a chemical element in our modern sense, and his view, which he borrowed from another philosopher, of the atomic structure of matter.

Under the inspiration of Boyle and his colleagues, chemical works of the second half of the seventeenth century exhibit in general a positive, cautious, experimental spirit, and show a great contrast to the mystical and obscure writings of the first half of the century, which have much affinity with Alchemy. A fine exponent of this new spirit was John Mayow (1645–79), who was prevented by an early death from fulfilling all his promise. He was the first to recognize clearly that there is a substance or principle in air which is concerned at once with combustion, respiration, and the conversion of venous into arterial blood. In this sense he was the discoverer of Oxygen (Figs. 74 and 75).

§ 8. *The Medical Theorists.*

The great advances in the physical and biological sciences, instituted during the sixteenth and seventeenth century, left the old medical theories derelict. We have already traced the wrecking of the Galenic physiology. With its destruction, the old ideas concerning the three types of spirit, natural, vital, and animal, went by the board. The doctrine of the circulation of the blood (p. 113) and the investigations of the new Chemistry accorded ill with the old humoral pathology, which

ascribed all disease to excess or defect of one of the four humours, blood, phlegm, bile, and melancholy (p. 34). Numerous fresh theories arose, of which the more important can be classed under the three headings *Iatrophysics*, *Iatrochemistry*, and *Vitalism*.

(*a*) *Iatrophysics.*

The physical discoveries of Galileo and the demonstrations of Sanctorius (p. 108) and of Harvey (p. 111) gave a great impetus to the attempt to explain the workings of the animal body on purely mechanical grounds. The writers who took this point of view are known as the *Iatrophysicists*. One of the earliest and most impressive exponents of physiological theory along these lines was the French philosopher René Descartes (1596–1650). His work on the subject appeared posthumously in 1662. It is important as the first modern book entirely devoted to the subject of Physiology.

Descartes had not himself any extensive practical knowledge of the subject with which he was dealing. On theoretical grounds he sets forth a very complicated apparatus which he believes to be a model of animal structure. Subsequent investigation failed to confirm his findings, and his work soon passed into oblivion. For a time, however, it attracted much attention and many followers. A strong point in his theory is the great stress laid upon the nervous system, and its power of co-ordinating the different bodily activities. Thus stated, his view may seem not far from the modern standpoint, though in fact he was grotesquely wrong in detail. An important part of his theory is the complete separation of Man from all the other animals. Man, according to

him, differs from all other animals by his possession of a soul, which is situated in a structure in the brain

FIG. 62. DESCARTES' conception of the relation of a sensory impression and a motor impulse. The image of the object ABC passes to the eye and is formed on the retina. Owing to the optical properties of the eye, it is there inverted. The image is inverted yet again within the brain, where it passes to the pineal gland H at the point *b*. The position and character of the image formed on the retina determines the nature and distribution of its effect on the pineal body. According to the nature and distribution of that effect is the result on the nerve, and through it, by the passage of nervous fluid, on the muscles. The movement in the nerve is initiated at the point *c*. The relation between *b* and *c* is an insoluble mystery in which is wrapped up the very nature of the soul. (From the posthumous work of Descartes on Physiology.)

known to physiologists as the 'pineal body'! Animals, he held, have no soul, and all their actions and movements, even those which seem to express pain or fear, are

purely automatic. It is the modern theory of 'behaviourism' with man excluded! (Figs. 62 and 63.)

More lasting was the achievement of Giovanni Alfonso Borelli (1608–79), an eminent mathematician who was professor at several Italian universities and the friend of Galileo and Malpighi. Stirred, like

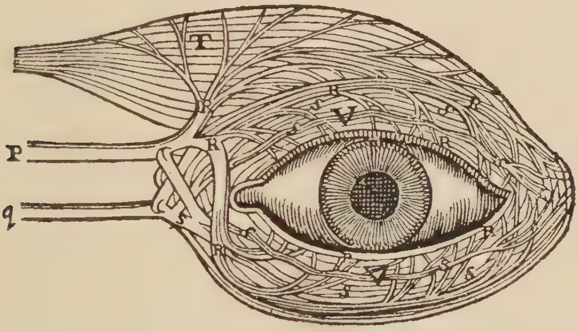


FIG. 63. DIAGRAM OF DESCARTES to illustrate his theory of nervous action. P R and *q s* are nerves which supply the muscles of the eye T and V V. Descartes held that these nerves were hollow and provided with valves, which can be seen at the point at which the P R and *q s* first branch. These valves were partly controlled by little fibrils (which can be seen in the main stems of P R and *q s* and in certain of their branches). These valves control the movement of the fluid within the hollow spaces of the nerves. Additional complication is lent to the scheme by the fact that P R and *q s* intercommunicate at certain points. The view of Descartes, and all such theories of nervous fluid, were destroyed by the experiment of Swammerdam (Figs. 57–60), which, however, long remained unpublished.

Descartes, by the success of Galileo in giving a mathematical expression to mechanical events, Borelli attempted to do the same with the animal body. In this undertaking he was, in fact, very successful. That department of Physiology which treats of muscular movement on mechanical principles was effectively founded and largely developed by him. Here his mathematical

and physical training was specially useful. He endeavoured, with some success, to extend mechanical principles to such movements as the flight of birds and the swimming of fish. When he came to an analysis of some of the other activities of the body, such as the action of the heart, or the movements of the in-

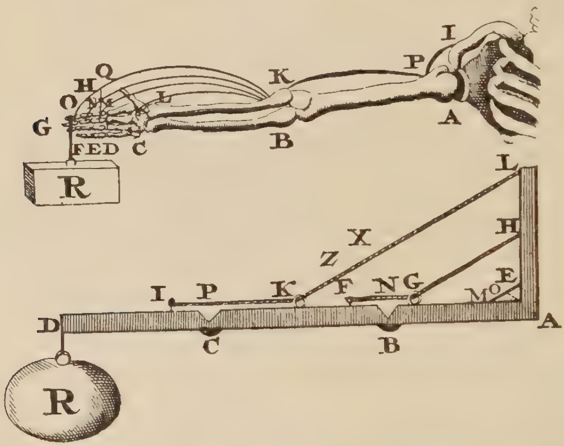


FIG. 64. DIAGRAMS FROM BORELLI, showing one of his attempts to analyse the movements of the muscles, in this case of the arm, according to the principles of the science of Mechanics as expounded by Galileo. The figure should be considered in conjunction with Fig. 65 opposite.

testines, he was less successful, and he naturally failed altogether in his attempt to introduce mechanical ideas in explanation of what we now know to be chemical processes, such as digestion in the stomach.

Undeterred by Borelli's failure, other writers sought to find mechanical explanations of physical processes. As is usual in such cases, the amount of theory was inversely proportional to the amount of knowledge. The views of some of the later 'Iatrophysicists' became very

fantastic. Belated representatives of the school are the writers of the great French *Encyclopédie* (1751–72), and notably its main author, the man of letters, Denis Diderot (1713–84).

(*b*) *Iatrochemistry.*

Just as there were some who sought to explain all animal activity on a mechanical basis, so others resorted

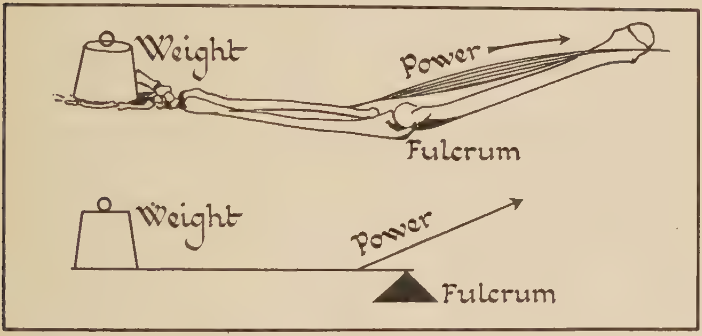


FIG. 65. DIAGRAM OF MUSCULAR ACTION involved in lifting a weight in the hand. It illustrates how muscular movement may sometimes be resolved into terms of the lever. In practice, however, it is usually necessary to involve a whole system of levers, pulleys, resistances, &c., as Borelli clearly perceived. (Compare Fig. 64.)

to chemical interpretation. These may be termed *Iatrochemists*. The most prominent was Franciscus Sylvius (1614–72), professor of Medicine at Leyden. That university had become, in the second half of the seventeenth century, the most progressive scientific centre north of the Alps. It was the seat of the first University laboratory, built at the instigation of Sylvius.

Sylvius devoted much attention to the study of salts. He recognized that they were the result of the

union of acids and bases, and he attained to the idea of chemical affinity—an important advance. He looked at the phenomena of life also from the chemical point of view. Well abreast of the anatomical knowledge of his day, and accepting the broader lines of mechanistic advance in Biology, such as the circulation of the blood and the mechanics of muscular motion, Sylvius sought to interpret other activities in chemical terms. His position and abilities as a teacher gave his views wide currency and he and his pupils occupy a large part of the field of medical theory until well into the eighteenth century.

Under the influence of this school, almost all forms of vital activity were expressed in terms of 'acid and alkali' and of 'fermentation'. The latter process was assumed to be of a chemical order, and no clear distinction was made between changes that are brought about by 'unorganized' ferments, such as gastric juice or rennet, and changes that are brought about by the action of micro-organisms, such as alcoholic fermentation or leavening by yeast. Nevertheless, the school of Sylvius and its immediate successors added considerably to our knowledge of physiological processes, notably by their examination of the body fluids, especially the digestive fluids such as the saliva, and the secretions of the stomach and of the pancreas.

(*c*) *Vitalism.*

Yet another school of medical theorists arose under the leadership of the German chemist and physician, George Ernest Stahl (1660–1734). Stahl is best remembered as the author of the famous theory of

phlogiston, a hypothetical substance with which bodies were supposed to part during the process of burning (p. 151). He is important in the history of science for his success in grouping chemical phenomena and therefore in systematizing the study of the subject. For our purpose, however, Stahl stands as the protagonist of that view of the nature of the organism which now goes under the term *Vitalism*. Though expressed by him in obscure and mystical language, it is, in effect, a return to the Aristotelian position and a denial of the view of Descartes. To Descartes the animal body was a machine. To Stahl the word *machine* expressed exactly what the animal body was not. The phenomena characteristic of the living body are, he considered, not governed by physical and chemical laws, but by laws of a wholly different kind. These laws are the laws of the *sensitive soul*. The *sensitive soul* of Stahl is, in its ultimate analysis, not dissimilar to the *psyche* of Aristotle (p. 32). Stahl held that the immediate instruments, the natural slaves of this sensitive soul, were chemical processes, and his Physiology develops along lines of which Aristotle could know nothing. This does not, however, alter the fact of his hypothesis being an essentially vitalistic one of Aristotelian origin.

The language and the theories of the Iatrophysicists, the Iatrochemists, and the Vitalists of the seventeenth and eighteenth centuries have long been discarded by men of science in the form in which they were originally propounded. Nevertheless, they represent three attitudes to the activities of living things which have present and current meaning. Each seems to present

some aspect of truth. Whether some physiological thinker will combine all three aspects into one coherent whole, it is for the future to decide. Yet it is certain that all three lines of approach remain of value, and the stimulus provided by each of the three inspires investigation at the present day. In this sense we enter on the period of modern Medicine in the seventeenth century. In this sense the foundations of modern rational Medicine may be said to have been laid by Borelli, Sylvius and Stahl, with Galileo, Boyle and Harvey standing behind them.

V

THE PERIOD OF CONSOLIDATION

(FROM ABOUT 1700 TO ABOUT 1825)

§ 1. *The Reign of Law.*

DURING the sixteenth and seventeenth centuries the human mind cast off its medieval vestments and, having refreshed itself at the spring of Antiquity, turned to array itself in the garments of the New Philosophy. The advent of new ideas and new knowledge had been very rapid. The *method* of Research had been determined by Galileo at the beginning of the seventeenth century. The *meaning* of Research was determined by a second great investigator, Newton, at the end of the same century.

The change wrought in the thought of their time by Vesalius, Galileo, Harvey and their like, was quantitative rather than qualitative. They discovered new laws of Nature, but the discovery of such new laws was hardly unprecedented. Law had been traced in the heavens from of old. The rules of planetary and stellar motion had been gradually developed from the simple astronomical theories of the ancients. The great astronomers of the sixteenth and seventeenth centuries did not hesitate to appeal to the records and doctrines of medieval writers, for new mathematical relationships of the heavenly bodies had been elicited even during the Middle Ages. In the sixteenth century Astronomy under Tycho (died 1601) put her house in order for the 'Great Instauration' of the coming age. And then Galileo startled the world (1604) with that new star

of his (p. 104), among the most remote heavenly bodies in the very region held by the Aristotelian and Platonic schemes to be utterly changeless. The Revolution in Thought had begun, though no new order had been established.

By 1618 Kepler had enunciated his 'three laws of planetary motion', bringing these movements into an intelligible relation with each other. Then the experimental philosophers set forth to establish terrestrial mechanics. They determined the mode of action of gravitation, and Galileo came near to the 'three laws of motion' which we call Newton's. But it was Newton who first affirmed them clearly and succeeded in linking them with Kepler's laws of planetary motion. Before Newton, no man had shown or perceived that rule by which the natural succession of earthly phenomena is in relation to that of the heavenly bodies. Nay, Faith and Reason alike would have been against such a view. To prove that the relationship amounted to identity, to move men's minds to see that the force that causes the stone to fall is that which keeps the planets in their path, this was Newton's unique achievement. It was Newton who first enunciated a law whose writ ran alike in the Heavens and on the Earth. With Newton the Universe acquired an independent rationality, and the whole cosmology of Aristotle, of Galen, and of the Middle Ages lay in the dust.

When Newton had completed his work, the Gravitation of the Earth and of the Heavens was seen to be one, and all the Mechanism of the Universe lay spread before him. The vision was set forth in his *Principia* (1687). It established a view of the structure and

working of the Universe which has survived to our own generation.

And now as to the change wrought in men's minds. It was something more than a Revolution. It was the establishment of a New Order. Newton conceived a working Universe wholly independent of the Spiritual Order. As to how far his vision is philosophically tenable and as to how far he realized its nature, these are matters which we need not discuss here. There can, however, be no doubt that Newton utterly destroyed the very foundations of medieval thought. With Newton there sets in the last stage of 'scientific determinism'.

During the two centuries and a half since the *Principia* appeared, Science has developed prodigiously along the lines into which Newton led her. In reliance on the universality of Natural Law, the stars in their courses have been paced, weighed, measured, analysed. The same process, directed to our own planet, has traced its history, determined its composition, demonstrated its relation to other bodies. Physicist and chemist have suggested a structure in terrestrial matter similar to that of the stars and suns. The world has been reduced to a unitary system. Wherever men have sought Law, they have found Law. With search skilful enough and patient enough, Law has ever emerged. It has been *the Age of the Reign of Law.*

It is true that in our own time philosophers in general have come to see that these Laws of Nature are within us as much as without; that they are, in part at least, the result of the structure of our minds. This is a point of view, however, which has not affected, and perhaps will not affect, the working man of science. His con-

stant occupation, since the days of Newton, has been the pursuit of Law, and he has always been satisfied that Law has only to be sought in order to be found. This conception has affected the medical and biological sciences very deeply. Thus the influence of the Newtonian philosophy is as traceable in them as it is in the astronomical and physical sciences. Galileo showed men of science that weighing and measuring are worth while. Newton convinced a large proportion of them that weighing and measuring are the *only* investigations that are worth while. The question as to whether this view is ultimately true or philosophically justifiable does not need discussion at the moment. The point, for our immediate purpose, is that the view has been and is very widely held.

§ 2. *The Rise of Clinical Teaching.*

The eighteenth century dawned with the refreshing breeze of Newtonian philosophy blowing through it. During the previous two hundred years there had been an immense amount of new and fruitful research along diverse lines. Chemistry and Mechanics, Botany and Comparative Anatomy, Descriptive Anatomy and Experimental Physiology, Epidemiology and Microscopic Analysis, all had yielded startling results. The new generation was bewildered with the very mass and novelty of the material. The Biologists of the time must have been wellnigh hopeless of reducing their vast accumulations to order, when they contemplated the beauty and symmetry of the mathematical relations that Newton and his followers had introduced into Cosmic conceptions. Thus the eighteenth century is

a period for Biology of pause and consolidation during which attempts were made to introduce unitary conceptions into the mass of accumulated material. It was, moreover, a period of consolidation not only of ideas but also of teaching. These tasks at first turned men's minds away from the immediate accumulation of further knowledge. So it is that the first half of the eighteenth century exhibits something of a gap in the progress of Research. The medical field is largely filled by two great figures, Boerhaave and Haller.

Until the seventeenth century there was no systematic clinical teaching. The Universities gave medical degrees on the basis of a spoken disputation. No contact with the patient was demanded. The first effective attempt to change this was at Leyden, where about 1636 clinical teaching was instituted. Owing to this, and to the fact that, as at Padua, students of every religious denomination were accepted, Leyden became much frequented by foreign and especially by Protestant students. The attractions of the place were increased by Sylvius (pp. 131–2) who, in the second half of the seventeenth century, added laboratory instruction to his clinical teaching. Leyden had several eminent anatomists, while its botanic garden and museums added to the practical character of the medical instruction that it offered.

Hermann Boerhaave (1668–1738) was first appointed as a teacher at Leyden in 1701. At once the medical school attained a front rank reputation which rapidly came to surpass even that of Padua. Boerhaave had very few beds at his disposal, but never did man make better use of his opportunities. Besides clinical,

chemical, botanical and anatomical instruction he followed such of his patients as died into the post-mortem room and there demonstrated to his students the relation of lesions to symptoms. He is thus the introducer of the method of medical instruction still in vogue in our modern medical schools.

Boerhaave was a man of wide culture. He rescued and published the plates of the priceless *Bible of Nature* of Swammerdam (p. 121). He brought to Leyden the best anatomist of his age, Bernard Siegfried Albinus (1697–1770). With him Boerhaave edited in superb form the collected works of Vesalius (1725, p. 85 ff.). The edition exhibits remarkable prevision of the scientific needs of the scholarship of our own time. To Albinus, and indirectly to Boerhaave, we owe the most beautiful of all works on muscular anatomy (1747), a book still in current use (Fig. 66). Apart from his clinical ability and acumen Boerhaave was a skilled chemist, botanist, and anatomist.

With all these accomplishments Boerhaave was better able than any man of his time to achieve something like a medical synthesis, to bring all the sciences to the service of the patient. Taking one thing with another, considering his influence as a teacher, his clinical acumen, his power of inspiring younger workers, his wide learning, his balanced vision, his eagerness for new knowledge, his sanity, his humanity, his generosity, and his prophetic power, Boerhaave must be regarded as the greatest physician of modern times. To him the debt of British Medicine, and through it of British well-being, is quite incalculable. Through his pupils he is the real founder of the Edinburgh

FIG. 66. TWO PLATES FROM BERNARD SIEGFRIED ALBINUS. *Anatomical Plates of the Muscles of Man*, Leyden, 1747. These are the most beautiful and among the most accurate anatomical figures ever published.

Medical School, and through it of the best medical teaching in the English-speaking countries of the world. The success of the Edinburgh school, founded while the great Leyden professor was still in his prime, can be ascribed to two causes which are perhaps reducible to one—the inspiration of Boerhaave. These two causes are, firstly, the enthusiasm of its early teachers, and, secondly, the concentration of all the medical teaching, both clinical and subsidiary, in one great university school.

§ 3. *Physiology passes to the Modern Stage.*

The only figure in the eighteenth century whose influence is comparable to that of Boerhaave is his pupil, the Swiss Albrecht von Haller (1708–77), one of the most accomplished men of all time. In actual scientific achievement Haller stands, indeed, far above his master. He achieved distinction as poet, botanist, anatomist, and novelist, carried on a prodigious correspondence, was an exceedingly learned bibliographer, and perhaps the most voluminous of all scientific authors. His special distinction, however, is as a physiologist.

Haller's great work, *Elements of the Physiology of the Human Body* (1759–66), marks the modernization of the subject of which it treats. Of the highest importance were his researches on the Mechanics of Respiration, on the formation of bone, and on the development of the embryo. He did good work on the action of the digestive juices. His most important contributions, however, are his conceptions of the nature of living substance and of the action of the nervous system. These conceptions formed the main background of

biological thinking for a hundred years, and are still integral parts of physiological doctrine.

All departments of Medicine must be influenced by the views we may hold on the nature and action of the nervous system, just as all parts of the body are influenced and indeed are linked together by that system. Thus the growth in knowledge of the physiology of the nervous system is extremely important to us if we would gain a true idea of the progress of Rational Medicine.

When we look into the history of nervous Physiology before Haller, we shall be struck by the smallness of the observational foundation of a vast speculative structure. That we may be the more charitable in our judgement of such fanciful developments, we may recall that the Mind is so constructed that it can take little interest in the accumulation of instances unless it can adduce general laws therefrom. Theory is thus as necessary to practice as practice to theory. The earlier doctrines of the nature of nervous action are, however, so unlike those we now hold that we can afford to pass over them lightly. They consist of speculations on the topic of the seat of the soul, together with explanations which suppose the passage either of a fluid or of some chemical change down the nerves. Haller was the first to construct a theory of the nervous system that has an appearance of modernity.

During the seventeenth century the favourite doctrine of nervous action supposed the existence of a nervous fluid. This, it was held, passed down the nerves to inflate or extend the muscle fibres. Inflation was supposed to shorten the fibres and so the muscle came to contract. An exquisite experiment by Swammerdam

with his nerve-muscle preparation had disproved this (p. 123). But Swammerdam's work was unknown till published by Boerhaave in 1736, and so the matter stood till Haller's time.

Haller concentrated the problem on an investigation of the fibres. A muscle-fibre, he pointed out, had in itself a tendency to shorten with any stimulus, and afterward to expand again to its normal length. This capacity for contraction Haller, following a predecessor, called *irritability*. He recognized the existence of 'irritability' as an element in the movement of the viscera, and notably of the heart, and of the intestines. The feature of 'irritability' is that a very slight stimulus produces a movement altogether out of proportion to itself, and that it would continue to do this repeatedly so long as the fibre remained alive.

But besides the force inherent in a muscle-fibre Haller showed that there was another force which comes to it from without, is carried from the central nervous system by the nerves, and is the power by which muscles are normally called into action. This force, like that of irritability, is independent of the will, and like it can be called into action after the death of the animal. Haller thus distinguished the *inherent muscular force* from the *nerve force*. Both these forces he further distinguished from the natural tendency to contraction and expansion, under changing conditions of humidity, pressure and so on, of all tissues, living or dead.

Haller, having dealt with the question of movement, turned to that of feeling. He was able to show that the tissues are not themselves capable of sensation, but that the nerves are the sole channels or instruments of this

process. He showed how all the nerves are gathered together into the brain, and he believed that they tended to its central part. These views he supported by experiments and observations involving injuries or stimulation to the nerves and different parts of the brain. He ascribed special importance to the cortex, but the central parts of the brain he regarded as the essential seat of the living principle, the Soul.

Throughout his discussion Haller never falters in his display of the rational spirit. He develops no mystical or obscure themes, and, although his view of the nature of Soul may lack clarity, he separates such conceptions sharply from those which he is able to deduce from actual experience. He is essentially a modern physiological thinker, and certain of his themes were developed by workers who come on the frontiers of what we have called the 'period of consolidation'.

Among these workers we would select the Scottish surgeon Sir Charles Bell (1774–1842), who in 1811 showed that of the two roots from the spinal cord by which all the nerves of the body arise one root conveys only sensory elements while the other conveys only motor elements (Fig. 98, p. 208). By this discovery Bell not only completed the views of Haller on the central nervous system, but also brought them within the range of practical Medicine.

§ 4. *Some Physiological Advances.*

Haller provided a philosophical basis to physiological conceptions. There were, however, other workers of the time who added to the knowledge of actual workings of the animal body. First among these,

both in time and eminence, stands the English country clergyman Stephen Hales.

The Rev. Stephen Hales (1677–1761) was by temper a biologist, but he had received a training in Mathematics and Physics. With this ideal equipment, he proceeded to investigate the Dynamics of the Circulation. His method consisted in applying the principle of the pressure gauge or manometer to living things. By tying tubes into the arteries and veins of animals, he was able to record and measure the blood-pressure. He thus laid the foundation of an important mode of studying and diagnosing disease. He extended his exact investigations into most of the mechanical aspects of the circulation. He computed the circulation rate and he estimated the actual velocity of the blood in veins, arteries, and capillary vessels. He made a very important contribution by showing that the capillary vessels are liable to constriction and dilatation, a knowledge that has since become not only important for physiological theory but of primary significance to the practising physician (p. 309). He began to explore the wonderful mechanism of the heart by which that organ adjusts itself to its needs of output. He exhibited his versatility by important contributions to many other departments, as, for instance, his discoveries on Respiration, his improvements in Ventilation (Fig. 67), and his campaign for Temperance. All his work is characterized by simplicity and directness, the supreme marks of his genius.

In the meantime considerable progress was made in the knowledge of the digestive processes. The French naturalist, René Antoine de Réaumur (1683–1757), best remembered for his thermometer (1731) and for

his superb work on insects (1734–42), made a series of experiments on gastric digestion in birds (1752). By an ingenious contrivance he succeeded in obtaining gastric juice in a pure state. He was able to demonstrate its

FIG. 67. WINDMILL VENTILATOR designed by the Rev. Stephen Hales, and erected by order of the Aldermen of the City of London, in 1752, on the roof of Dick Whittington's Gate at Newgate Prison. From a print in the British Museum.

power to dissolve food substances in a test-tube kept at body temperature. This was important, since many believed that the process of solution was the result of a churning process induced mechanically by the muscles of the stomach-wall. Réaumur thus gave the death-blow to the Iatrophysical conception of digestion (p. 130).

The investigation of gastric digestion was further pursued by a versatile Italian, the Abbé Lazaro Spallanzani (1729–99), who showed that the churning action is an aid, but not an essential, to the process of digestion (1782). He proved that digestion was not of the nature of putrefaction and differed essentially from the fermentation of wine. Spallanzani thus improved on the view of Sylvius (p. 132), and took a step towards that solution of the natures of putrefaction, fermentation, and digestion which was finally provided by Pasteur (p. 225). He showed that the gastric juice was secreted by the stomach itself, and not introduced into it from other organs. A suspicion that the gastric juice contained a free acid crossed his mind. He observed that it curdled milk and so began our knowledge of a separate ferment, that of 'rennet'. Spallanzani's results may be summarized by saying that he showed that gastric juice had a solvent power *sui generis*, and that this power or faculty was of a different order from putrefaction or vinous fermentation.

The phase of digestive physiology represented by Réaumur and Spallanzani was brought to a close by the English physician William Prout (1785–1850), who demonstrated in 1823 the existence of free Hydrochloric Acid in the stomach. He showed that the presence of this acid was necessary for gastric digestion, but that the actual process of solution of food was the work of another agent. The matter was at last brought into the range of medical practice by an American Army Surgeon, William Beaumont (1785–1853), who, in the ten years ending 1833, had the opportunity to investigate gastric juice in a man who, having been shot in the stomach, had a permanent fistula. Through

this the juice could be obtained and the lining membrane of the stomach examined at will.

An important department of Physiology was opened by the extension of the knowledge of electric phenomena to the living body. Static electricity had been studied since the beginning of the seventeenth century. Luigi Galvani (1737–98) of Bologna, while investigat-

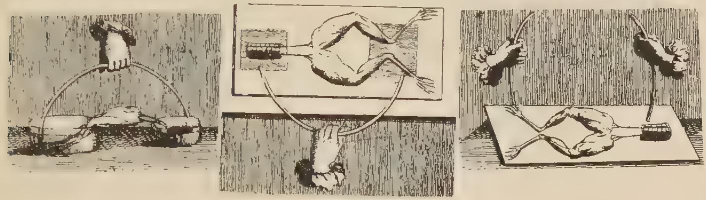


FIG. 68. FIG. 69. FIG. 70.

Experiments illustrating the effects of metallic contacts on the nerves and muscles of frogs' legs. From A. Galvani, *On Electric Forces*, 1792.

FIG. 68. Contact is established between water in two dishes. In one lies the end of the nerve with the spinal cord and vertebral column attached. In the other are the feet of the frog.

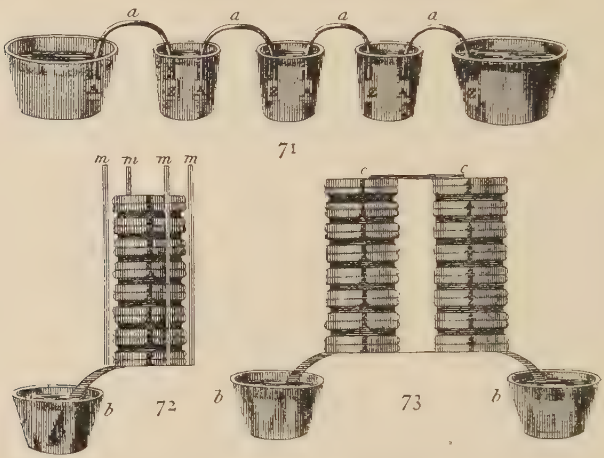
FIG. 69 shows contact by a metal bar with two damp mats on one of which lies the spinal cord and on the other are the feet.

FIG. 70 shows a broken contact which can be completed by bringing the metal rods together.

ing the susceptibility of nerves to irritation, showed that nervous action could be induced by electrical phenomena (1791). He was, as a matter of fact, producing an electrical current. Many thought at the time that a new kind of 'animal electricity' had been produced and they dubbed it 'galvanism'.

Alessandro Volta (1745–1827) of Pavia, deviser of the 'Voltaic pile' (Figs. 71–3), had long been working at electricity. He was able to demonstrate (1800) that

galvanism is without any essential animal relationship, and showed that a muscle can be thrown into continuous contraction by repeating electric stimulations.



FIGS. 71, 72, and 73. From an article by Volta, *On the Electricity excited by the mere Contact of Substances of different kinds*, published in 1800.

FIG. 71 is the famous 'Couronne de tasses'. It consists of a series of vessels containing salt water, in which are steeped plates of alternate silver A and zinc Z. The plates are connected by strips of metal *a a a*. If the first and the last cup be connected by a conductor, a current flows from one to the other.

FIG. 72 is a simple voltaic pile, consisting of alternate disks of silver and zinc, sandwiched between wet strips of leather. The pile is held by glass rods *m m m*. From the lowermost disk a strip of metal passes to a vessel containing salt water. A current will pass from the uppermost disk to the vessel if the two are connected by a conductor.

FIG. 73 is a similar apparatus with two piles connected by a metal plate *c c*, and two vessels *b b*. A current will pass between the two vessels *b b* if they are joined by a conductor.

Humbug and misunderstanding in connexion with the electrical relations of living tissues were rife, and it was not till after the period we are now considering that electricity came to take a place in rational Medicine.

The change came with E. Du Bois-Reymond (1818–96), who took the matter up scientifically about the middle of the nineteenth century (1843 onwards). He showed that a nervous impulse is accompanied by the passage along the nerve of a change of electrical potential. It should be added that, despite all the work since done upon the nervous system, this is still the only physical accompaniment of a nerve impulse that has been detected.

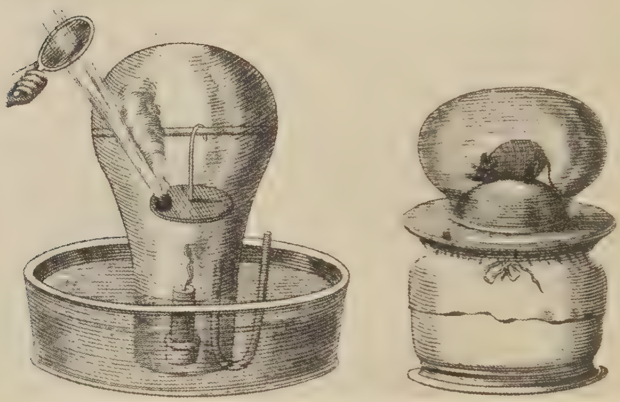
§ 5. *Discovery of the Nature of the Air.*

The seventeenth century saw advances in the knowledge of the air. Boyle (1654, p. 124) had shown by means of his air-pump that air was a material substance and could be weighed. By exhausting the air from a vessel in which an animal had been placed, he showed that it was this material substance and no ether, spirit, or other mysterious entity which supported respiration. Mayow (1668, p. 126) proved that a part only of the air was necessary for life, and later that this same part was removed equally by respiration and combustion (Figs. 74–5). His work was forgotten for a hundred years. The great theorists, Stahl, Boerhaave and Haller, knew him not, and Stahl's doctrine of *phlogiston* set back the hands of the clock. No advance was made till the work of Joseph Black (1728–99) which appeared soon after the middle of the eighteenth century.

Black was a cautious investigator and his success was due to the accuracy of his measurements. He was aware of the fact that chalk, when heated, is transformed into quicklime (equation 1, p. 152), thereby losing its power of effervescing with acids, but gaining the power of

absorbing water (equation 2). In modern nomenclature, the changes are:

$$(1) \quad CaCO_3 = CaO + CO_2$$
$$(2) \quad CaO + H_2O = Ca(OH)_2$$



74 75

FIGS. 74 and 75, illustrating the chemistry of burning and breathing, from a work issued by Mayow in 1674. The experiments show the essential similarity of the two processes in their effect upon the air.

FIG. 74. A candle is burning and a piece of inflammable material is being ignited in a glass vial by a burning-glass, the mouth of which is under the surface of the water. The air can, if desired, be changed or sampled through the attached tube.

FIG. 75. A mouse confined under a glass cover. The air under this cover communicates with that in the vessel below, and can be cut off more or less completely by means of a more or less porous diaphragm.

The first achievement of Black was to show that in the process of heating the chalk lost weight (equation 1). This was a blow at the phlogiston theory, for it had been supposed that quicklime consisted of chalk *plus* phlogiston, and that the phlogiston was conveyed to it during the heating. Black now showed that if slaked

lime be treated with a mild alkali, such as the carbonate of sodium, it is changed back to the state in which it was before heating, in fact into chalk, while the mild alkali is converted into a caustic alkali. As we now express it:

(3) $Ca(OH)_2 + Na_2CO_3 = CaCO_3 + 2NaOH$

Black's triumph consisted essentially in showing that reactions (1) and (3) were indefinitely reversible and that the same amount of $CaCO_3$ could always be extracted from (3) as was put into (1). Moreover, he showed that a definite amount of chalk, whether heated into quicklime or not, neutralized an equal weight of acid, the only difference being that the neutralization took place with effervescence and loss of weight if the chalk were unheated, and without effervescence or loss of weight if the chalk were first heated into quicklime. Thus:

(4) *Unheated* $CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2$
(5) *Heated* $CaO + 2HCl = CaCl_2 + H_2O$

The substance given off by the chalk in (1), absorbed by it in (3), and produced by the reaction (4), he named *fixed air*. We now call it *Carbon dioxide*. The conversion of caustic lime into ordinary chalk by exposure, $CaO + CO_2 = CaCO_3$, proves that Carbon dioxide is a normal constituent of the atmosphere. Black learned something of its properties, and his work is also of very great importance as the first detailed quantitative study of a chemical reaction and its reversal. The properties of Carbon dioxide were further investigated (1766) by Henry Cavendish (1731–1810).

The next advance in the chemistry of the air was

made by the English Unitarian Divine, Joseph Priestley (1733–1804). A series of important observations was made by him in the seventies and eighties of the eighteenth century. He showed that green growing plants

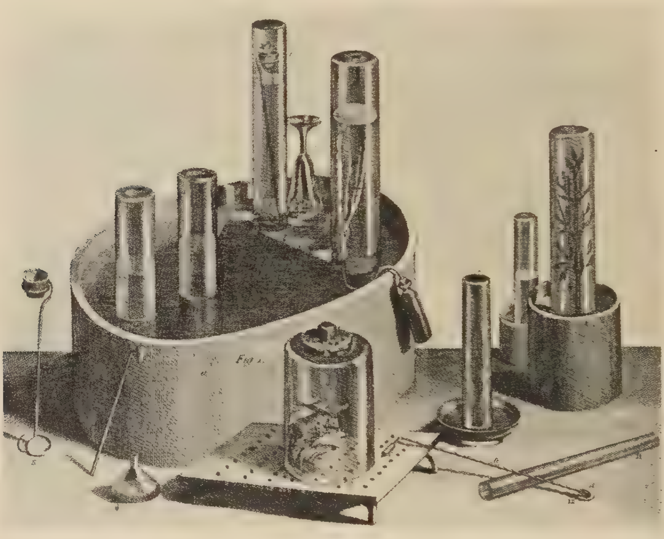


FIG. 76. APPARATUS from Joseph Priestley's *Experiments and Observations on different Kinds of Air*, Birmingham, 1774. In the background can be seen an experiment on the effect of combustion on confined air. There are also two cylinders inverted over water in which green plants are growing. In one of them the growing plant has given off a gas (oxygen) which Priestley showed could support both combustion and respiration. In the foreground under a bell-jar are some mice on which Priestley performed respiratory experiments.

would make respired air again respirable, and that they gave off a respirable gas. In 1774 he prepared Oxygen by heating certain oxides, though, still hampered by the phlogiston theory, he failed to recognize the nature of the oxygen he had produced. The conclusions of his

striking experiments on blood, which he showed to depend on this same agent for its changes from venous to arterial, were similarly vitiated.

The real passage to the modern point of view in our knowledge of the air was made by the brilliant French

FIG. 77. LAVOISIER in his laboratory making experiments on breathing. To the right Madame Lavoisier sits at a table, taking notes. Lavoisier stands behind, directing. To the left is the subject of the experiment. His face is covered with a mask provided with a valve. He is breathing into the apparatus. An assistant feels his pulse while a second assistant collects the respired air in a bell-jar inverted over a trough
From a contemporary sketch.

chemist Antoine Laurent Lavoisier (1743–94). He made an extensive quantitative investigation of the changes during breathing (Fig. 77), burning, and calcination. In the course of these he discovered the true composition of respired air, and showed how both Carbon dioxide and water are normal products of the act of breathing. If clear grasp of the implication of

discovery be made the test, Lavoisier must be regarded as the discoverer of Oxygen.

Cavendish (1731–1810) had already discovered the composition of water (1785). Lavoisier concluded that water and Carbon dioxide are produced by the process of oxidization in the lungs, and that it is this oxidization process, and not any innate quality of a mysterious character in the body or in the blood, that is responsible for the bodily heat. Lavoisier introduced much of the chemical nomenclature that we still employ. So far as respiration is concerned, subsequent research has added much to his standpoint. In the purely chemical aspect, however, it has altered little, though we now know that the tissues and not the lungs are the seat of oxidation.

§ 6. *Morbid Anatomy becomes a Science.*

The main intellectual movement of the seventeenth and eighteenth centuries had been focused, so far as Medicine was concerned, on the manner of working of the animal body, the department that we now term Physiology. It was necessary to obtain clear concepts of the action of the body in health before venturing into discussion of its action in disease. Towards the end of the seventeenth century, an industrious compiler had put together all the then published records of post-mortem examinations up to his time. During the first part of the eighteenth century many practitioners in Physic and in Surgery published isolated cases or groups of cases connected with particular diseases. Boerhaave regularly attended post-mortem examinations (p. 140). No general pathological principles had,

however, yet been elicited on a scientific basis. The theories of disease such as those of Boerhaave were perforce still mainly speculative, for there were no extensive records of the correlation of symptoms during life with the appearances of the organs of the body after death, the subject we now call 'Morbid Anatomy'. This gap was first effectively bridged by Morgagni.

Giovanni Battista Morgagni (1682–1771) was professor at Padua for no less than fifty-six years. During this time he performed an enormous number of post-mortem examinations, and made important contributions to Descriptive Anatomy. In his seventy-ninth year, eleven years before his death, there emerged from his enormous experience his work *On the sites and causes of disease*. This classical treatise may still be read with profit. Its leading feature is the very careful way in which actual cases are recorded. The life-history of the patient, the history of his disease, the events in connexion with his final illness and death, are all recounted with detail and care. The condition of the organs at the post-mortem examination is minutely described and an attempt is made to explain how the symptoms were the result of the lesions. Morgagni is justly said to have introduced the 'anatomical concept' into the practice of medicine. This concept is one of the main elements in modern diagnosis, and a modern physician, in reflecting on a case, considers first whether he is able to express the symptoms in terms of lesion. There are many lesions of great importance and frequent occurrence which Morgagni was the first to describe.

The task which Morgagni had undertaken was

worthily continued by the Scot, Matthew Baillie (1761–1823), nephew, pupil, and heir of William Hunter (p. 165). Baillie was a successful London practitioner. He followed a new and convenient method in arranging his work according to organs instead of by symptoms,

FIG. 78. PART OF THE LUNG OF DR. SAMUEL JOHNSON, from a drawing published by Matthew Baillie. Johnson was a fat, unwieldy man, with a great barrel chest, who suffered for many years from shortness of breath. These are common associations with the pathological condition known as *Emphysema*, in which the lungs, which are normally of fine spongy texture, become full of abnormally large cavities, so that, as Baillie remarks, they come ' to resemble the air cells of the lungs of amphibious animals ' (cf. Fig. 45, p. 116). In the figure B represents the external part of the lung and A its cut surface. On the cut surface the large cellular structure can be seen. The very dark points are the orifices of cut branches of the pulmonary vessels.

as Morgagni had done. Baillie performed post-mortem examinations on several men of eminence, among them Dr. Johnson, whose lung he describes (see Fig.).

The task of naked-eye pathological anatomy, effectively begun by Morgagni, was effectively completed by Karl Rokitansky of Vienna (1804–78). His work (1842–6) was based on an experience extending over

30,000 post-mortems! Though disfigured by a bizarre theory, it left but few gaps for subsequent workers. From now on, the science of Pathology was to be prosecuted in a new spirit and with new instruments. Even in his own day Rokitansky was something of an anachronism, with his pure naked-eye anatomy hardly ever involving experimental evidence on the one hand or the findings of the microscope on the other.

§ 7. *Clinical Methods and Instruments.*

The great teachers of the earlier eighteenth century, though better equipped as regards knowledge than their predecessors, had hardly any better means of diagnosis. Pulse-measurers and thermometers such as those of Sanctorius and Galileo (p. 109) had proved impracticable by the bedside. The microscope had not yet entered into Clinical Medicine. Chemical analysis as applied to disease had proved, as yet, of little value.

The first efficient instrument of precision to merit clinical adoption was the 'pulse watch', by Sir John Floyer (1649–1734), an English provincial physician. It was introduced as early as 1707 as a 'Physician's Pulse Watch' and was an instrument constructed to go for just one minute. At that time the making of a twenty-four hours watch with a seconds-hand presented great mechanical difficulties. Floyer's invention was not widely adopted at the time. Attempts were also made to introduce a thermometer into practice, but again the construction of suitable instruments proved impossible.

Effective pulse watches and clinical thermometers did not penetrate into the general practice of Medicine till well into the nineteenth century. Two instru-

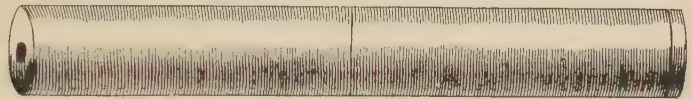
mental advances of first-class importance to Medicine were, however, introduced during the later eighteenth century. These were the methods of Percussion and Stethoscopy.

Percussion of the surface of the body yields notes of varying degrees of resonance. Its application has proved of great value to the physician in outlining the position of the organs and of lesions, especially those of the chest. It was invented by Leopold Auenbrugger (1722–1809), a Viennese physician who first introduced it in 1761. Like the thermometer, it was very slow in entering the general practice of Medicine.

Auenbrugger deserves great credit for his invention, but he did not work out its application with anything like the completeness that the Breton physician, René Théophile Hyacinthe Laënnec (1781–1826), applied to his 'stethoscope' (1819). Laënnec's instrument was of the uni-tubular type that is now seldom seen. At first, indeed, he used a mere roll of paper. His idea was rapidly diffused into every country.

But Laënnec did far more than introduce a useful and convenient device into Medicine. He explored with extraordinary skill the physical signs in the chest which correspond to a large number of diseases. The major part of our chest-lore and much of the technique and nomenclature of chest examination come direct from him. Despite continual bad health and the shortness of his life, Laënnec's brilliance and devotion to duty at a hospital in Paris enabled him to transmit his views and methods to many other physicians, both French and foreign. He is unquestionably among the greatest physicians of all time. Clinical medicine

assumes with him a completely modern aspect. In reading his work one feels that, had he been called in consultation by a medical man of our own day, the two would have been able to understand each other perfectly, after only a little adjustment and explanation.



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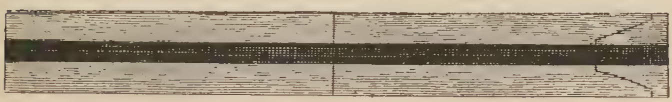

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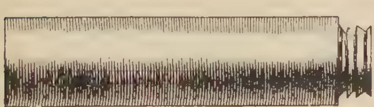

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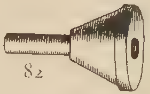

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FIGS. 79–82. LAËNNEC'S WOODEN STETHOSCOPE, from his work of 1819, *On Instrumental Auscultation*.

FIG. 79 is the complete instrument.

FIG. 80 is the instrument in section.

FIG. 81 is the ear-piece unscrewed.

FIG. 82 is the detachable chest-piece terminating in a thin metal tube.

§ 8. *Surgery and Obstetrics.*

During the eighteenth century the improved knowledge of Normal and Pathological Anatomy was a great aid to the surgeon. The technique of Surgery was certainly improved. Operations were now being performed with success that could not before have been attempted. Nevertheless few important new principles were introduced until long after the nineteenth century had dawned. It is indeed probable that as a means of life-

saving Surgery had an almost inappreciable effect on vital statistics until the advent of Anaesthesia and Antiseptics. Even the greatest surgeon of the eighteenth century, John Hunter, introduced no fundamental new surgical principles. True, the names of many surgeons of the period have become associated with operations invented or introduced by them, but it was not till after the advent of antiseptic methods that these were practised with full success. There are but two surgical matters in which advances of great significance can be said to have been made. These were the treatment of Venereal Disease and the treatment of Labour.

Syphilis, which existed in Europe in the later Middle Ages, had usually been confused with Leprosy and other conditions (p. 98). Its treatment by Mercury had been practised at least as early as the fifteenth century, perhaps as an inheritance from the Arabic-speaking physicians. During the sixteenth and seventeenth centuries various other remedies were tried (Fig. 33); much quackery arose around them. In the eighteenth century the accumulated experience of generations returned again to Mercury. Satisfactory methods of administration were evolved and the treatment became standardized. It hardly changed until the twentieth century.

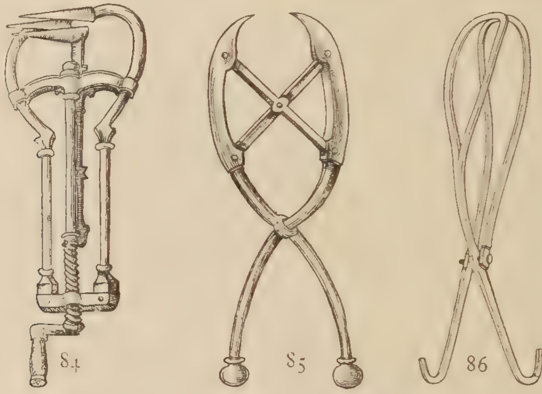
The treatment and care of women in Labour made considerable progress during the period of which we are treating. We have seen how there were advances even during the sixteenth century (p. 93) by such a writer as Paré. Works on obstetrics intended for women were often printed in the sixteenth century in France, England and Germany. Scientific obstetric

works were produced especially in France in the second half of the seventeenth century. The obstetric forceps was known, but was still a family secret. At the time

FIG. 83. LYING-IN SCENE in the sixteenth century from a contemporary work on midwifery. Drinking and feasting is going on in the room where, in addition to the patient, there are two men, five women, and two children. A dog chews a bone on the floor, cooking is in progress in the adjoining room. Food and drink is being forced on the unfortunate patient herself. The whole scene, which is intended to portray an upper-class household, suggests carousal, disorder, and dirt, as well as ignorance of the most elementary principles of hygiene.

and for long after, there was a great objection on the part of pregnant women to treatment by men. The midwives were for the most part ignorant, dirty, unskilful and superstitious, and the loss of life and health

that resulted from their mishandling was enormous. The objection to the 'man midwife' was only gradually overcome, though his advent was unquestionably



Early obstetric instruments.

FIG. 84 is the very dangerous and brutal *Speculum matricis* used to force open the mouth of the womb in cases of difficult labour. A similar instrument had been used since antiquity to dilate wounds.

FIG. 85 is an even more terrible and powerful instrument, the *Apertorium*, provided with a sharp edge by means of which the mouth of the womb was violently cut or torn.

In the seventeenth century less heroic measures began to be used, and the obstetric forceps was introduced.

FIG. 86 shows a pair of obstetric forceps as used in the seventeenth century. The instrument is the direct ancestor of that now in use, which, however, is a vast improvement upon it. The obstetric forceps were invented by a member of an hereditary family of man midwives, at the beginning of the seventeenth century. The nature of the instrument was long kept a secret. This particular instrument was found by accident in 1813, having been hidden under the floor by a member of the family of the inventor.

attended by a fall in the mortality. About the middle of the eighteenth century, moreover, the obstetric forceps came into wider use. One of the ablest and most successful of the obstetric physicians was

William Hunter (1718–83), the brother of John Hunter.

Despite the absence of any great new principle in the surgery of the period, there can be no doubt that a new spirit was introduced by John Hunter (1728–93). His complex and interesting character demands better treatment than it has yet received. As an

FIG. 87. JOHN HUNTER'S COUNTRY HOUSE at Earl's Court, Kensington, before its demolition in 1886. This house was in the country in Hunter's day, though its site is now a busy part of London. For many years he used it as a laboratory and menagerie, and much of his best work was done there.

investigator his powers were superb, but, like Leonardo, he was handicapped at every turn by literary incoherence. Nevertheless, with him Surgery begins to appear, at last, as a real Science and not as a mere applied Art. Hunter brought to bear on the subject a mind stored with ideas drawn from Comparative Anatomy and Pathology. Quick to detect analogy, shrewd in his scientific judgements, tireless and unsparing of himself in his pursuit of truth, a victim of disease self-inflicted in the service of science to which

he was tragically a martyr in his death, he shows as a heroic figure, rendered no less heroic by some very human failings. Fully to appreciate so incoherent a writer, it is unfortunately necessary to wade through many works written in his own clumsy and ill-arranged manner. To gain any real idea of this great personality we must consult the writings of his contemporary colleagues.

So far as actual advances are concerned, two may be connected with Hunter's name. Firstly, in the treatment of the deadly condition known as 'Aneurysm' he introduced a method of operation which is still in vogue. Secondly, he enormously improved the method of making and ordering a museum. His monument is the Hunterian Museum in London, based on his specimens of which many may still be seen there. The museums of Natural History, as now constituted in all civilized countries, have been influenced by, if they have not been derived from, that which he literally gave his life's blood to found. He was right when he said musingly in his illness, 'You will not easily find another John Hunter.'

§ 9. *The Beginnings of the Science of Vital Statistics.*

Attempts to combat widespread disease and to improve the public health are to be found in the history of all civilizations, both ancient and modern. Nevertheless, the rational method cannot come into operation until it has exact data upon which to work. Such data may be numerically expressed, a fact first appreciated by the versatile English physician and inventor, Sir William Petty (1623–87), who is usually regarded as the father of the science of Political Economy. In 1662,

and on many subsequent occasions, he joined a friend in issuing *Natural and Political Observations upon the Bills of Mortality* of London. In this work he endeavoured to deduce population, death-rates, disease prevalence, and other matters of vital statistics from the crude figures of the day. He was fully aware of the imperfection of his materials, and on this account he urged the necessity of providing a system and a government department for the collection of trustworthy statistics. In his *Political Arithmetick* (1683), the basic work of modern Economics, he displays ideas of a very modern character. Among these is his view that the true wealth of a country is to be sought in its efficient man power.

A number of Petty's fellow members of the Royal Society began to take interest in statistics. Chief among these was Edmund Halley, the astronomer (1656–1742). Toward the end of the century (1693) Halley produced a mass of statistics on the chances of life at various ages, designed for the estimation of the price of annuities. During the eighteenth century numerous writers devoted themselves to similar investigations. An important contributor to the mathematical basis of vital statistics was the French Huguenot and friend of Newton, Abraham de Moivre (1667–1754). His *Doctrine of Chances* (1715) and his *Annuities upon Lives* (1725) are important contributions to the subject. His celebrated hypothesis that among a body of persons over a certain age the successive annual decrease by death may be esteemed as nearly equal (that 'the decrements of life are in arithmetical progression') was under discussion for a century, but is now accepted.

In 1761 a Prussian clergyman, J. P. Süssmilch

(1707–82), produced an extraordinary theological work, *The Divine Ordinance manifested in the Human Race through Birth, Death, and Propagation.* Its object was to exhibit God's design in the constancy of the numerical relationships of vital statistics. Despite the motive—somewhat unpromising for a scientific treatise—the work is of great historic and scientific importance, for it was based upon a vast mass of statistics and showed a great advance in method. It stressed the importance of accurate data and the necessity for numerous observations, if reliable conclusions were to be drawn. From the time of the publication of the work of Süssmilch, the statistical study of population advanced rapidly. The basis of statistics was greatly improved by the introduction of the census system which was put into action in England in 1801.

The science of vital statistics was placed on a firm foundation by the Belgian astronomer Lambert Quetelet (1796–1874). His principal work, *On Man and on the Development of his Faculties, An Essay on Social Physics*, contains an account of his statistical researches on the development of the physical and intellectual qualities of man and on the 'average man' both physically and intellectually considered. He followed this in 1848 by his treatise, *On the Social System and the Laws which govern it.* In it he shows how the numbers representing the individual qualities of man may be grouped round the numbers referring to the average man in a way corresponding to the principles of the theory of probabilities. This conception, elaborated and further analysed, has formed the basis of all subsequent researches in vital statistics.

§ 10. *Military, Naval, and Prison Medicine.*

The eighteenth century saw some of Petty's principles put into practice. There was, as yet, but one section of public life in which scientific principles of preventive medicine could be applied. Only in the Army and Navy were the sufferers from disease under adequate control and observation, and only there were proper statistics of sickness and health available. Thus, many of the most important movements in Preventive Medicine during the eighteenth century, both in England and other countries, were initiated by naval and military surgeons.

Among military medical reformers an important place is taken by a Scottish pupil of Boerhaave, Sir John Pringle (1707–82). He had a large military experience in the British army, occupied a position of great influence, and was able to get many of his views and reforms generally accepted. Pringle was among the first to see the importance of ordinary putrefactive processes in the production of disease, and quite the first to apply these principles in hospitals and camps. Important conclusions on these matters were published in his *Experiments upon Septic and Antiseptic Substances, with Remarks relating to their Use in the Theory of Medicine*, which appeared in 1750. He identified 'gaol fever' or typhus with 'hospital fever'. He laid down important rules for the hygiene of camps which involved avoidance of marshes, proper drainage, and adequate latrines. His most permanent service was probably his suggestion that army hospitals should be regarded as neutral, and be mutually protected by belligerents. This great

physician is a good illustration of the 'new humanity' which came into public life in the eighteenth century. In much of that movement one may feel the influence of that most humane of physicians, Hermann Boerhaave (pp. 140–1).

Hardly less important than the work of Pringle for the Army was that of his brother Scot, James Lind (1716–94), for the Navy. Lind was a pupil's pupil of Boerhaave. He had a long naval experience and in 1753 wrote an important work on Scurvy, then a very common and fatal disease at sea. He demonstrated how this might be prevented by the adequate use of fresh fruit or, when this was not available, of lemon juice. Fresh water had always been a difficulty of sea voyages. Lind arranged for sea-water to be distilled for the purpose. He introduced rules for the prevention of typhus on ships, and made great improvements in naval hygiene. His essay of 1757 *On the most effectual means of preserving the Health of Seamen* is a classic. He also wrote an important *Essay on Diseases of Europeans in Hot Climates*, which opened the campaign for the conquest of the tropics (p. 270).

Lind, like Pringle, is one of a type that is very fully represented in the eighteenth century. A worthy representative of that school was Captain James Cook (1728–79), the explorer, who adopted Lind's principles. He established a record in one of his voyages to the South Seas. The voyage lasted three and a half years, and many hardships had to be endured, but out of 118 men only one died, and he was consumptive when he embarked from England. Of a different type was the Manchester health reformer, Thomas Percival (1740–1804), who

worked to introduce the reforms of Pringle and Lind into civilian life. The work of Percival leads on naturally to Southwood Smith and Chadwick (pp. 193–5).

The eighteenth century was essentially a period of individual effort. The time was not yet ripe for public action on a large scale in matters of Hygiene. Pringle, Lind, and Percival had, however, their humanitarian parallels among prison reformers. Scientific attempts to improve the ventilation and sanitation of prisons had been instituted by the Rev. Stephen Hales (pp. 146–7). None brought greater devotion to the task than John Howard (1726–90), a native of London who spent his vigorous powers in investigating the prison system. His researches extended to the hospital, quarantine and prison systems of France, Flanders, Holland, Germany, Italy, Greece and Turkey (Fig. 88). His reports were directly instrumental in the improvement of the hygiene both of prisons and hospitals, as well as in the institution of special fever hospitals in many countries. Some aspects of Howard's work were carried on by the great Quaker philanthropist Elizabeth Fry (1780–1845), others came within the field of activity of Southwood Smith and Chadwick (pp. 193–5).

The eighteenth-century humanitarian movement was active and had many able representatives in the United States. Foremost among them was Benjamin Franklin (1706–90), while in the ranks of Medicine none takes a higher place than Benjamin Rush of Philadelphia (1745–1813). Rush was particularly revolted by public punishments, to the abolition of which he devoted much energy. In matters of Hygiene Rush was ahead of his time. He wrote on the hygiene of troops and laid

special stress on fresh air and cleanliness of body and mind as an aid to health. He had a peculiar horror and repulsion for alcoholic intemperance. He was responsible for the first systematic work on insanity published in America. He left a fine account of a Yellow Fever epidemic at Philadelphia, and he approached the truth in his view that the disease arose in Philadelphia itself and was not brought as an infection from without.

§ 11. *The Industrial Revolution.*

During the eighteenth century the character of English civilization became modified by a factor which has since profoundly influenced all civilized countries. There was a rapid increase in the number and size of the towns. The main cause of this was the transformation of Industry by the use of mechanical power. The change that resulted in the life and outlook of the people was very profound. These changes and the causes that gave rise to them are usually spoken of as the 'Industrial Revolution'. That revolution had effects that were both wider and deeper than followed any other such single upheaval in history. With the mechanical elements that were at the back of the Industrial Revolution, such as the improvements in transport, the invention of industrial machinery (Fig. 90), the enclosure of common land, the new position of agriculture, we are not here directly concerned. What does affect our story is the increasing urbanization of the population, which began early in the eighteenth century, increased rapidly soon after the middle of the eighteenth century, and has progressed continuously ever since. In this matter England is but

FIG. [illegible]. AN EIGHTEENTH CENTURY QUARANTINE STATION (Naples)
From John Howard's *An Account of the principal Lazarettos in Europe*, Warrington, 1789

a type, for all other civilized countries followed in her wake, though at a somewhat later date.

Along with the growth of towns and the increased population there was an increased demand for food. The country became better cultivated and better drained, and there were many improvements in agriculture. Thus, certain diseases began to diminish, notably Malaria, essentially a disease of undrained and ill-cultivated lands. The expulsion of this disease, as of Typhus, was the work of the nineteenth century (p. 283).

It is often assumed that the physical evils of life became accentuated by the rise of the great towns. Nevertheless, investigation shows that the opposite has been the case. During the eighteenth century men and women began to crowd into the great towns from the country. They were, in fact, right in their choice, for their chances of life there were greater than upon the land. In the rural districts infamous housing conditions, an overcrowding beyond anything which we now encounter, exposure to weather, uncertainty and fluctuation in the prices of commodities, low wages, unpassability of roads in winter time, inaccessibility of medical aids, combined to render life, and especially child life, more precarious than in urban areas.

The improvement of hygienic conditions in the towns began in England soon after the middle of the eighteenth century. Westminster obtained an Improvement Act in 1762, Birmingham in 1765, the City of London in 1766, Manchester in 1776, and most of the other provincial towns soon followed. As a result of such Acts noisome streams which were but open drains were covered in, the streets were paved and lighted, and

89

90

FIGS. 89 and 90 illustrate the passage of the textile trade from home industry to factory work with the consequent break-up of the family as the labour unit. Textiles were the first important articles of commerce to be thus affected, but others rapidly followed. The pictures are typical of the Industrial Revolution.

the sewers improved. There were still many glaring defects of sanitation which have occupied and still occupy reformers, but by the end of the eighteenth

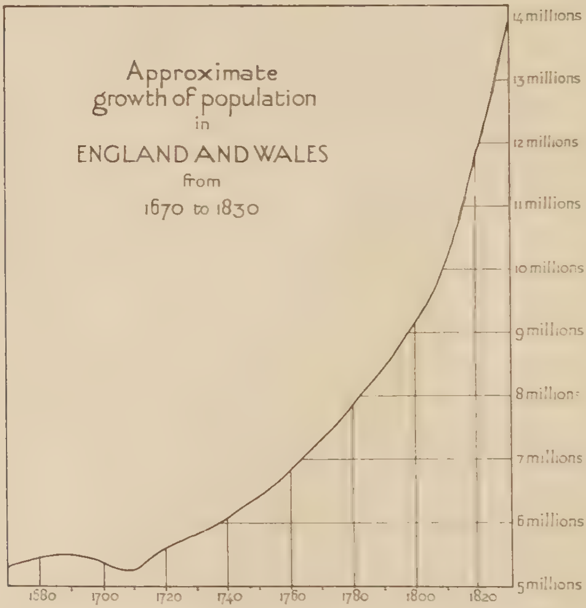


FIG. 91 shows how the population of England and Wales started to increase rapidly about 1750, with the beginning of the Industrial Revolution. The chart covers a period in which statistics were not exact. The figures for it have had to be estimated, but they are probably accurate as round numbers. The census returns are available from 1801.

century the general appearance of a street in one of the more advanced cities was much what it now is. The change from the medieval conditions of a century before was at least as great as the changes that have since taken place.

But if the streets had improved there was much

3383

Age	1730–9	1740–9	1750–9	1760–9	1770–9	1780–9	1790–9	1910–12 Males	1910–12 Females
10	36·9	37·0	37·3	36·9	36·7	37·5	38·2	—	—
20	29·1	28·9	29·2	29·3	29·4	29·9	28·4	42·35	46·71
30	23·7	23·5	23·8	24·1	24·1	24·9	24·4	33·87	37·94
40	19·6	19·2	19·4	19·6	19·5	19·5	19·5	26·03	29·67
50	16·1	15·8	15·7	16·1	15·9	15·7	15·8	19·09	22·17
60	12·2	12·4	12·1	11·9	11·9	12·0	11·9	13·09	15·39
70	9·4	8·6	8·7	8·5	8·3	8·7	8·5	8·17	9·57
80	5·9	5·7	5·7	5·7	5·7	6·3	6·2	4·79	5·39

Showing the expectations of life in London for each decade from 1730–1800, with recent data for comparison.

N

Age	1730–9	1740–9	1750–9	1760–9	1770–9	1780–9	1790–9	1911–12
10–20	6·5	5·9	5·9	7·1	8·2	7·1	6·5	—
20–30	17·5	17·6	17·2	17·9	17·3	16·4	15·1	3·7
30–40	27·1	26·3	26·1	25·2	25·0	23·9	23·7	6·2
40–50	36·6	38·6	35·9	36·3	35·5	35·4	34·3	11·7
50–60	45·5	47·9	45·7	42·1	45·0	44·7	44·6	21·1
60–70	61·4	63·4	63·7	64·4	62·8	64·7	64·1	40·3
70–80	83·7	98·3	96·4	101·8	105·0	101·7	104·4	87·3
80–90	143·1	150·4	151·0	153·0	152·7	153·0	155·1	181·9

Showing the death-rates at Age groups in London for each decade from 1730–1800, with recent data for comparison.

FIG. 91A. TABLES showing that vital conditions in the eighteenth century did not deteriorate but improved with the Industrial Revolution.

under and around them which would horrify us now. Water-supply, as in London, was usually drawn mainly from surface wells and rivers. In most towns a continuous water-supply was unknown. Even when water mains existed, the supply to the houses was limited. Thus, even in the early nineteenth century London houses had a water-supply only three times a week, and then only for a few hours at a time. The water mains were often defective, and there was not always that clear distinction between a water main and a sewer that we now regard as desirable. Floods were a constant trouble in all riverside towns. Cesspools were in use even in London as late as the middle of the nineteenth century, and water-closets did not become general, even in the better houses, until about 1828. The methods of disposal of sewage hardly bear relation. In London the sewage simply polluted the rivers.

The improvement of such conditions as these could only be made by State action. The eighteenth century did well where individual activity was concerned. It was reserved for Southwood Smith (p. 193) and Chadwick (p. 194) to introduce into the sphere of practical political action the truth, set forth by Bentham (pp. 190–2), that all factors which influence the health of the country must be the concern of the Legislature.

We gladly pass from this darker picture to the Hospital and Dispensary Movement which took its rise about the middle of the eighteenth century. Many of the great hospitals both in England and in Continental countries were either founded or rebuilt about this time. Thus, the London Hospital was rebuilt in 1752, St. Bartholomew's in 1730–53. Between 1700 and

Fig. 42. St. Bartholomew's Hospital at Smithfield, London, in 1720

1825 no less than 154 hospitals and dispensaries were founded in the British Isles. Though defective from the modern point of view, yet under the influence of the sanitary reformers, Hales (p. 146), Pringle (p. 169), Lind (p. 170), and Percival (pp. 170–1), these were incomparably better equipped, better ventilated and better found than such institutions would have been at the beginning of the eighteenth century. The notes of the industrious Howard (p. 171) give us a very complete picture of them, and one that is more favourable than might, perhaps, have been expected.

A defect of the hospitals of the time was certainly the nursing. This, however, was somewhat better in the Lying-in-Hospitals, where the services of a higher type of woman were available and where ladies served on the committee of management. The general state of the hospitals remained much the same until transformed by the changes in surgery and nursing in the second half of the nineteenth century, though a number of special fever hospitals and pest-houses were established.

Something must be said of the more prevalent diseases of the Industrial Revolution. Stress is often laid on the effect of urban conditions on child life. Yet there can be little doubt that historically the movement has been beneficial to it. This comes out well in the death-rates. Thus, in England in the period around 1740, before the industrial revolution had begun, about 75 per cent. of children born died before the age of five. In the period around 1800, when the industrial revolution had set in, the percentage of deaths had fallen to about 41. In the period 1915–24

it was about 14. Among the most characteristic diseases of children is Rickets. It is very difficult to trace the early history of this disease, but its incidence seems to have been very high about 1700, and to have fallen progressively throughout the eighteenth century. This fall, it has been suggested, was due to agricul-

FIG. 93. A VIEW OF THE PEST HOUSE in Tothill Fields, London, in 1796. From a print in the British Museum.

tural improvements which led to better supplies of better-fed meat. It was these improvements and better supplies that, in their turn, made the big towns possible.

We have already spoken of Scurvy on ships. It was, however, well known on land, especially in winter when green vegetables were not to be had. Lind (p. 170) in 1753 found it common in the land population. The advances in agriculture removed it altogether from the land diseases during the eighteenth century.

§ 12. *Control and Recognition of Epidemic Diseases.*

Over one department of public health there was State supervision during the eighteenth century. The ports were guarded against the introduction of Epidemic Diseases, and especially against Plague. Throughout the eighteenth and early nineteenth century there was Plague in the Near East which extended at times to various parts of Europe. It was epidemic in Russia in 1709 and some 150,000 died of it. In 1719 it spread to Eastern Central Europe. One historic outbreak was at Marseilles and Toulon in 1720, when 90,000 died. The outbreak caused great alarm in England, but did not reach this country, nor has there since been any outbreak here. Quarantine is now regarded as antiquated, vexatious, inhumane, expensive, and ineffectual. It seems probable, however, that during the eighteenth century, when drastically enforced, as in France with the Marseilles epidemic, it had indeed the effect of keeping the disease within bounds. Incidentally, it led to the foundation of many plague hospitals or Lazarettos, of the conduct of some of which Howard (p. 171 and Fig. 88) speaks well.

During the eighteenth century Small-pox was never absent from this country. From time to time the disease became epidemic, and there were grave and fatal outbreaks. Thus, in 1774 there was an outbreak of small-pox at Chester. Next year an investigation was made of the degree to which the population had suffered. It was then found that before the outbreak there were in Chester only 15 per cent. who had not already had the disease. The incidence on those unprotected by a

previous attack was 53 per cent., with a death-rate of about 17 per cent. of those actually infected and of about 9 per cent. of the entire unprotected population.

With the certainty of contracting small-pox before their eyes, men sought a way of getting it in a mild form. Outbreaks of small-pox varied greatly in virulence, and infection with a mild form would lead to protection from a graver one. In the East a method of direct inoculation of the disease from a patient suffering from a slight attack was widely in vogue from an early date. The practice attracted little attention in Europe until Lady Mary Wortley Montagu (1689–1762) studied it at Constantinople. It was then soon taken up in England, and became recognized on the Continent.

The efforts of Lady Mary in England were reflected on the other side of the Atlantic. The famous Puritan leaders, Increase Mather (1639–1723) and Cotton Mather (1663–1728), turning from their exploits against the witches, ardently urged the operation. In England the learned Dr. Richard Mead (1673–1754), an eminent and far-seeing physician who exercised very great influence on the medical world in his day, published in 1747 a work in which he supported the practice of inoculation with all the weight of his authority. During the subsequent half-century the practice spread widely. The operation was largely in the hands of specialists who were not always medical men.

Such was the state of affairs when the country practitioner Edward Jenner (1749–1823) came upon the scene. In 1796 a dairymaid became infected with a

disease of the udders of cows, distantly resembling small-pox. She developed pustules on her hand. Jenner inserted a little of the matter from one of these into the arm of a boy of eight, who developed typical cow-pox. Jenner next inoculated this boy with small-pox, which, however, failed to develop. The evidence, so far as it went, was complete. It is an entire justification of what might seem nowadays to be a reckless experiment, that

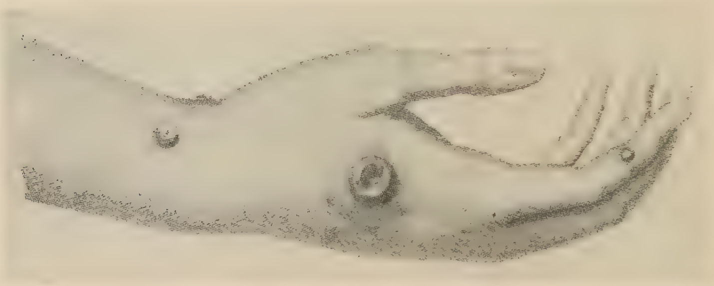


FIG. 94. HAND OF DAIRY-MAID infected with cow-pox from a cow's udder. From Edward Jenner, *Inquiry into the Causes and Effects of the Variolae vaccinae, a Disease discovered in some of the Western Counties of England, particularly Gloucestershire, and known by the name of the Cow Pox,* London, 1798.

at that time inoculation of small-pox was a normal and effective defensive procedure. The disease of cows has since become known as Vaccinia, and the process of inoculating it as *Vaccination*.

The discovery of vaccination, important though it be, is a mere trifle compared to the train of new work and new thought that has been opened out by it. The whole study of Immunity, which has now become an independent science, arises from it. The work of Pasteur (p. 225), Lister (p. 239), and Koch (p. 234), and a large

part of modern therapy, are among the achievements of this movement.

Besides Plague and Small-pox, many other epidemic diseases became more clearly understood during the period we are considering. Among these was Scarlet Fever, the history of which is particularly interesting for the variations which it has shown in virulence. It first became clearly recognizable as a mild disease without prominent symptoms about 1650. Good observers in the half-century that followed considered it a new disease. In England it continued to be of little importance till about 1748, when it began to be associated with grave throat symptoms and to be confused with Diphtheria. This phase continued for about ten years. The virulence then dropped and the disease continued of slight consequence till 1785. It then grew virulent again and remained so till about 1808. The malignancy then fell again and remained low for about thirty years. It rose about 1837 and from then till 1884 it was one of the great killing diseases, especially of childhood. Since then, the mortality from it has steadily decreased.

During most of its history Scarlet Fever has been liable to greater or less confusion with Diphtheria. The clinical distinction was first clearly made in 1826 by Pierre Bretonneau of Tours (1771–1862), who gave Diphtheria its present name. The same French physician performed the first successful tracheotomy in a case of Diphtheria. He is also known for pioneer work in the recognition of Typhoid Fever.

VI

PERIOD OF SCIENTIFIC SUBDIVISION

(FROM ABOUT 1825 ONWARDS)

§ 1. *Origins and Implications of Scientific Specialization.*

WE have seen how the philosophy of Newton, with its implication, the Reign of Law, which is the Uniformity of Nature, has come to pervade scientific thought (p. 137). Now, before Newton as after him, there were certain natural divisions of scientific activity corresponding, in some degree, to the types and faculties of men. Since Science first began there have been Mathematicians, Biologists, Physical Experimenters, because in fact the particular powers which enable a man to reach distinction in one of these departments are of less value in the others. Until the period of which we are now to treat, investigators were accustomed to explore at large within these great departments. Such specialist professions as Actuarial Calculators, Economic Entomologists, Physical Chemists, or, in the department of Medicine, Medical Statisticians, Aural Surgeons, or Vaccine Therapists —familiar to us now—were unknown and undreamt of then. This subdivision is a new thing, and is a characteristic product of the period of which we have now to treat. The subdivisions, unlike those of old, are largely artificial. Thus, the Aural Surgeon who deals with the organ of hearing cannot be separated clearly by his training, his powers and faculties, his operative skill, nor even perhaps by his field of work, from the Stomatologist who deals with the mouth, or the Rhinologist who deals with the nose. Nevertheless these

minute subdivisions are convenient and beneficent in medical as in other departments. The question of scientific specialization is so important and characteristic that we must examine it a little farther.

It is often thought that, since no man can compass all knowledge, this scientific subdivision is merely an attempt to compass a part of that growing mass of knowledge which is becoming progressively less compassable in its entirety. The movement, however, both in origin and development, is less simple than this, for there never was a time when a man could know all that was known about his world. In this respect our own age is even as other ages. Were the view philosophically tenable—which it is not—that Science becomes yearly less comprehensible, our outlook would be gloomy indeed. For since there is no evidence of any increase in the mental capacity of the human race—at least in historic time—such a view would imply a progressive diminution in the number of those competent to treat any wide scientific area, and a corresponding progressive separation from each other of minds with scientific insight. Fortunately such conditions do not prevail; the view that they do is simply due to a gross, yet widespread, misconception of the nature of Science.

Equally fallacious is the idea, which has become diffused by the existence of scientific specialization itself, that the progress of any science is to be measured by the mass of observations that its votaries have succeeded in accumulating. This is far from being the case. The advance of a science is measured by the degree with which it succeeds in bringing a multiplicity of observations under general laws.

Judged by this standard, we should probably rate very highly, for example, the present state of what is called *Demography*, the study of the life conditions of communities, while we should rank much less highly, for example, the present state of the study of Aural Surgery. Yet, for one publication on Demography there must be many on Aural Surgery. In the one case, however, the accumulation of knowledge follows a well-directed and rational scheme. In the other it is prompted and occasioned by the immediate needs of individual sufferers. This must not be considered as derogatory to those whose task it is to treat the sufferers. The point is that the one department, of its nature, exhibits the rational spirit better than does the other.

Since Rational Medicine is the subject that we treat here, we shall select for discussion those departments which best illustrate its spirit. This does not imply, and is not meant to imply, any belittlement of the less fortunate departments. On the contrary, the less any scientific department has succeeded in eliciting general laws, the more necessary it is that those most capable for the prosecution of such advance should devote their attention to that department. It may, indeed, reasonably be urged that a leading defect in our scientific organization is that men of scientific insight crowd to just those studies where their special powers have already been best exhibited.

In previous chapters, dealing with more remote times, we have been able to place our facts in historic perspective. Despite the enormous mass of scientific literature dating from the seventeenth, eighteenth, and early nineteenth centuries, there is no real obstacle to

selecting what is most important in it. True, it is beyond the power of any one student to examine all this literature at first hand, but it has been arranged and indexed, posterity has passed its verdict, and the historian can find his way through the thicket. It is also true that important advances are sometimes forgotten, as happened to Mayow's discovery of Oxygen in the seventeenth century (pp. 126, 151), which was repeated by Priestley a hundred years later (p. 154). But the fact that we know of such neglected discoveries shows that, however unjust the fates may have been to Mayow, yet his influence has not been underestimated by later historians. The History of Science, therefore, can up to a certain point be written along the same lines as political or economic history.

The face of affairs changes, however, when we pass into a period which differs for different topics, but may be roughly defined as beginning somewhere between about 1820 and about 1870. We then begin to encounter the very questions with which men of Science are occupied in our own time. Since many of these questions still remain unsettled, it is impossible for the historian to say with certainty which are the most fruitful lines of work. The most he can hope to do is to distinguish the most influential and stimulating thinkers and observers from those who have been less so, and to say something about the ideas with which the more important schools of thought were instinct.

When we look into the origin of the system of specialization, whether in Medicine or in any other department of Science, we shall find certain philosophical tendencies at work of which the modern man

of Science is the heir, though often the unconscious and sometimes the ungrateful and even the misunderstanding heir. Neither men of Science nor medical men are always philosophers, or at least not always consciously so. Nevertheless, they are as surely influenced by the streams of thought of their time as they are by their heredity and their physical environment. The general tendencies of Medicine in this or in any other age cannot be interpreted without some reference to the intellectual atmosphere in which it has arisen and in which it has flourished.

The intellectual atmosphere in which scientific specialism arose was that of the so-called 'Utilitarian Philosophy'. Many of the dicta of that school, which came into prominence toward the end of the eighteenth century, are still used as part of the language of men of science and others. 'The greatest happiness of the greatest number' is a formula launched upon our common speech by Joseph Priestley (1733–1804, p. 154). The pursuit of such happiness as the main object of human activity is taught by the 'Utilitarian' philosophy, a word coined by the English political and social thinker, Jeremy Bentham (1748–1832). To Bentham, the founder of that philosophy, we owe such useful additions to our language as 'codification' and 'international', and these, together with 'utilitarian', give us some clue to the character and mode of his thought. It is probable that no thinker had a larger share than Bentham in ushering in the era of the subdivision of the sciences.

Bentham made a sustained attempt to draw a parallel between the physical and the social sciences, and this

gave him a special influence over medical thinkers and especially over those that dealt with the public health. His pupil, John Stuart Mill (1806–73), speaks of his master's mode of working as 'the chemical method'. It is thus not remarkable that Bentham should exert a

FIG. 95. A CARTOON OF THE EARLY NINETEENTH CENTURY illustrating the condition of children in the factories of the time. A bale is directed to Sir Robert Peel. This is the first Baronet (1750–1830), father of the statesman. Peel the elder was a cotton-spinner who imported from the London workhouses deserted children whom he treated well, but used to work his factories in Lancashire. He was a Member of Parliament and in 1802 carried the Act which was the forerunner of all factory legislation, *An Act for the Preservation of the Health and Morals of Apprentices and others, employed in Cotton and other Mills.*

profound influence on Medicine, both directly and indirectly. The peculiarly logical, uncompromising and perhaps un-English character of his mind, while it prevented him, fortunately for himself, from taking an active share in the task of government, did not prevent

him from influencing those who did. Specifically, he is the direct begetter of our modern system of organization of the Science of Preventive Medicine.

§ 2. *The Revolution in Preventive Medicine.*

Of all the many changes in Medicine and Medical thought that the Period of Scientific Subdivision has witnessed, none have been more revolutionary than those in the department which deals with Preventive Medicine. Great and important reforms were introduced during the course of the eighteenth century. These, however, even when the result of legislation, were the outcome of the effort of individuals, or were concerned with the Army and Navy (p. 169). In the period that follows, the Public Health becomes a general political, legislative, and administrative matter, and 'Prevention' becomes its watchword. The public consciousness—moralists will call it the public *conscience*—had been aroused, and has never again entirely slept. The chief agent in the awakening process, the intellectual force at its back, was and is Jeremy Bentham.

Rational Medicine has, in general, no national frontiers. To it men of all the national units have made important contributions. But the care of the Public Health in the period on which we now enter, being an affair of legislation and administration, has developed along national lines and it is difficult to discuss it save on a national basis. It is a source of justifiable national pride that Britain has, from the first and throughout, been the leader of the Public Health movement. But while we lose little and gain much by telling the story

from the British point of view, it has still to be remembered that, just as Rational Medicine has, fortunately, no spiritual frontiers, so, unfortunately, sickness and suffering have no physical frontiers. Epidemics pass the most scientifically constructed boundaries upon the surface of the map, and without a passport. In our time this evident proposition has obtained, at least, formal recognition. International health legislation has at last appeared. A future historian of Rational Medicine will be able to write his chapter on the Public Health from the point of view of Humanity at large. The historian who has the misfortune to be born too early must still content himself with treating the subject along national lines.

(a) *Preventive Medicine in Britain.*

If Bentham be the spiritual father of Public Health legislation, the protagonists whose names must be associated with the development of the movement along practical lines in England are Thomas Southwood Smith (1788–1861) and Edwin Chadwick (1800–90).

Thomas Southwood Smith was a Unitarian minister, and long combined this office with that of physician. Settling in London in 1820 he came under the influence of Bentham. By his essay on *The Use of the Dead to the Living* he did something to remove the odium attached to dissection. The scandals of the time and the common sense of the 'utilitarians' (p. 190) led to the passing of the Anatomy Act of 1832. Thus by a proper legal process bodies became available for dissection by medical students. Bentham died just before this Act became law and by his will left his body to Southwood

Smith to be the subject of dissection and of an anatomical lecture.

Southwood Smith's services to the spread of interest in Public Health were very numerous. He circulated a simple and popular *Philosophy of Health* (1835). He served on a board of inquiry as to the condition of children in factories (1832, cp. Fig. 191), and he was especially useful to the Poor Law Commissioners by reason of his exceptional knowledge of fevers. He was the founder of a 'Health of Towns Association' (1840), and of another association for 'improving the Dwellings of the Industrial Classes' (1842). In 1848 he became a member of a new government department, the 'General Board of Health' (p. 195). His official reports on Quarantine (1845), Cholera (1850), Yellow Fever (1852), and on the results of sanitary improvement (1854), were of world-wide use.

Edwin Chadwick (1800–90), who was not a medical man, introduced to public notice what he called the 'sanitary idea', a conception that coloured the whole of his extraordinarily active life. He sat on Government Commissions on Poor Law, on Police, and on the investigation of the condition of factory children. One of his Reports (1833), issued while he and the century were both in the early thirties, recommended a system of inspection with a view to limiting children's hours of work. The current system of pensions and of trade instruction to soldiers and sailors is the descendant of a scheme of Chadwick's devising. An item in the evidence attached to one of his Reports is the public provision of open spaces for recreation, a topic of current interest at the moment of writing.

At the time of the accession of Queen Victoria in 1837 Chadwick was agitating for the appointment of a Sanitary Commission. Two years later, as a result of a grave epidemical outbreak in London, the Commission was appointed. Its reports, which drew wide attention at the time, have had a large share in determining the general course of health legislation in the ninety years that have since elapsed. The scientific basis of health legislation can only be determined if proper vital statistics be available. The Registration Act of 1838, under a developed form of which we still live and die, was in essence his work. If we search into the history of any department of the scientific treatment of the Public Health, we shall always ultimately work back either to Southwood Smith or to Chadwick and through them to Bentham.

Among the most important documents for which Chadwick was responsible was the *Parliamentary General Report on the Sanitary Conditions of the Labouring Population of Great Britain* (1842). It came to fruit in 1848 with the *Public Health Act*, which established a new governmental department, the 'General Board of Health' (p. 196). The same year saw the passage of the *Nuisances Removal and Diseases Prevention Act*, by which summary action in such matters was rendered possible on the complaint of specially authorized local authorities. Just as the Board came into action there was an outbreak of Cholera in England, of which 54,000 persons died. The statistics available under the new system made possible the deduction that the infection is conveyed by drinking-water and led to suitable precautions. This is one of the many instances in which the

practice of prevention of a germ-borne disease preceded any knowledge of its organic cause, or indeed any direct knowledge of disease germs at all.

The first town in England to appoint a Medical Officer of Health was Liverpool. The City of London followed in 1848, when Simon took office. After

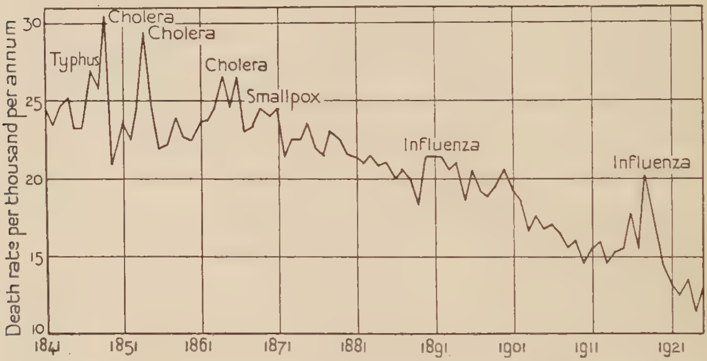


FIG. 96. ANNUAL DEATH RATE IN LONDON PER THOUSAND LIVING OVER A PERIOD OF 85 YEARS.

It will be seen that the curve begins definitely to take a downward trend about 1870. It has been falling ever since. It is now less than half of what it was sixty years ago. This fall is largely, though not entirely, due to decrease in infant mortality. Some of the more important epidemics are indicated. Typhus disappears as an important cause of death in the forties and Cholera and Smallpox in the sixties. Since then the death-rate has been considerably modified by Influenza outbreaks.

Southwood Smith and Chadwick, Sir John Simon (1816–1904) was the foremost figure in the history of the Public Health of this country. He later became medical officer to the 'General Board of Health'. The work of this Board—together with its medical officer—was taken over, for political and administrative reasons, by the Privy Council. The medical department of the Privy Council became in 1871 part of the

Local Government Board, the medical functions of which were absorbed by the new Ministry of Health in 1917.

To Simon are due the abolition of urban cesspits and improvement of the system of sewers, and the institution of sanitary inspectors and legislation concerning housing and overcrowding. One important result of these measures was that it became possible to abandon the cruel and wasteful system of quarantine that had been of value in the eighteenth century. Simon's plan, which was gradually adopted, was to trust to the same preventive methods for foreign as for native infections. This was, of course, only possible with an efficient sanitary service such as he succeeded in instituting. Such measures were aided by laboratory investigations, begun by a small staff. At first largely occupied with examinations in connexion with actual outbreaks, its scientific functions rapidly grew. Working on a wider basis, these functions have been performed for the nation since 1911 under the direction of the Medical Research Council.

(b) *Preventive Medicine in the United States.*

In the United States the history of the national Public Health Service has been very different from that of the English system. The same philosophical tendencies have been at the basis of the American as of the English system. In the United States, however, the National Service has been linked with the Army and Navy in a manner quite foreign to British traditions. The Federal health system had its origin in the old Marine Hospital Service, first authorized by Congress

in 1798. This enabled the President to appoint medical officers at ports and elsewhere for the purpose of giving medical treatment to disabled merchant seamen. The funds were obtained by a tax on those employed on American vessels.

The first marine hospital under the Act was at Norfolk, Va., in 1800. In 1802 a marine hospital was built for the port of Boston, and from time to time hospitals were built at other important seaports. To provide for the relief of seamen on inland waters Congress passed in 1837 an Act for the appointment of a board of advisory medical officers of the Army. A number of hospitals were established on its advice.

The evolution of public health functions from this service was along natural lines. The medical officers, in providing care for the American merchant marine, were often the first physicians to diagnose such diseases as Cholera, Yellow Fever, Smallpox and the like, which were being imported into the United States. In the epidemics of Cholera which occurred in certain ports of the United States the marine hospitals and their medical officers were utilized for the relief of those suffering from the disease. During the Civil War the marine hospitals, together with the medical officers,

Description of Fig. 97.

A 'Seamen's Hospital Society' was founded in England in 1817. Its first hospital was the *Grampus*, an old 50 gun ship moored off Greenwich. This was succeeded in 1830 by the *Dreadnought*, 104 guns, and this in 1857 by the *Caledonia*, 120 guns, renamed *Dreadnought*. In 1870 this last wooden *Dreadnought* was broken up and the patients were transferred to a building on shore close by. The darkness, damp, ill-ventilation, noisiness and septic character of a wooden ship made it thoroughly unsuitable for hospital purposes.

In 1899 the 'Seamen's Hospital Society' established a special Hospital and School for Tropical Diseases such as are peculiarly common among seamen.

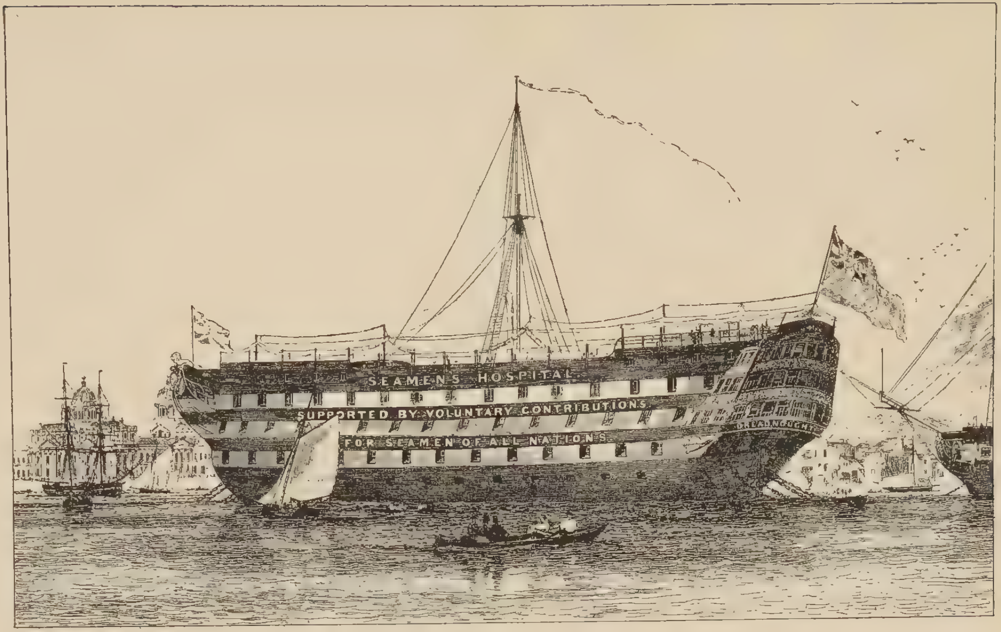


Fig. 97. THE OLD *DREADNOUGHT* HOSPITAL SHIP.

See note opposite.

were used by the military authorities, both North and South, for the care of the military forces.

Not until 1878 did Congress authorize any extensive use of the Marine Hospital Service as a Federal Health Service. An Act of 1878 gave broad powers to the Service to co-operate with State and local health authorities in the control of disease, especially of Yellow Fever. In 1890 Congress decided to utilize the Marine Hospital Service as the Federal Health agency for the prevention of inter-State spread of Cholera, Yellow Fever, Smallpox and Plague. In 1893 the powers of the Marine Hospital Service in this regard were extended to cover all infectious and contagious diseases, in co-operation with State and local health agencies.

The efficiency of the Marine Hospital Corps in the control of epidemic diseases became widely recognized. In 1889 Congress passed an Act which made possible the further organization of the Marine Hospital Corps, and provided that the officers be commissioned in grades similar to those of the medical department of the United States Army. An Act of 1875 had already provided that the Surgeon-General (supervising surgeon) should be appointed by the President, with the consent of the Senate.

In 1893 the Marine Hospital Service was organized into the Federal Health Service. Congress continued to impose additional health functions upon the Service, and in 1902 changed its name to the 'Public Health and Marine Hospital Service' and made it a health service in name as well as function. The larger part of its duties, up to this time, had been the combating of epidemics, especially those of Yellow Fever, which from time to time swept the country. With the threat of

Bubonic Plague in 1900 at San Francisco, the Marine Hospital Service was placed in charge of control methods and succeeded in preventing any extensive spread of the disease.

In addition to the quarantine and hospital functions, the activities of the Service soon came to include research and educational work. In 1902 Congress authorized the establishment of the Hygienic Laboratory for investigating Cholera, Yellow Fever, and other conditions. The Laboratory grew rapidly and is now a very important research institution, equipped for carrying on pathological, zoological, pharmacological, bacteriological, chemical, and physiological work.

From the control of epidemics, the Public Health and Marine Hospital Service began to develop control measures for the more common contagious and infectious diseases, such as Typhoid Fever, Diphtheria, and Scarlet Fever. The history of the wonderful control of Typhoid Fever which has taken place in the United States within the past twenty years is a part of the history of the Public Health Service in co-operation with State and local health agencies. Typhoid fever, which formerly took a toll of more than 50,000 lives annually, is responsible for the death of a mere fraction of this number at the present day.

The development of health functions of the Public Health and Marine Hospital Service continued until Congress in 1912 changed the name to its present one, the 'United States Public Health Service', and at the same time gave it broad powers to investigate the diseases of man and the pollution of navigable streams and lakes.

During the courses of Federal development the

separate States of the Union were not devoid of protagonists of State intervention in matters of public health. Among these was Lemuel Shattuck (1793–1859), who, like Chadwick, was no medical man, but a student of social problems. Under the influence of Chadwick he drafted in 1850 the *Report of the Massachusetts Sanitary Commission*. This publication set forth a complete scheme of Public Health organization. The formation of the first State Board of Health in Massachusetts was, however, delayed till 1869. In this matter Massachusetts was, in fact, anticipated by Louisiana, which obtained a State Board of Health in 1855, and by New York City, which obtained a Board of Health in 1866. Most of the States followed in the seventies. The seventies and eighties were the decades in which the general principles suggested by the work of Pasteur and Koch were put into effect. The working hypothesis of sanitarians of the time was that filth and ill-drainage were direct factors in the production of epidemic disease. The view is now untenable, but there was unquestionably an immense improvement in health conditions resulting both directly and indirectly from the improved drainage, water-supply, housing, and the like that the agitation had stimulated.

As the bacteriological discoveries of the time became generally accepted, they were widely applied on American soil to the administrative control of disease, notably by the New York Department of Health under Hermann M. Biggs. That body, in 1892, instituted a bacteriological laboratory, the scope of which has steadily increased. Its work in connexion with Diphtheria is elsewhere discussed (pp. 265–6).

To follow into our own time the development of factory legislation, vital statistics, school medical service, local health authorities, municipal laboratories and clinics, methods of food inspection, would be to write a text-book of Public Health Administration. In all these developments we see working the rational spirit in the peculiarly English field of Preventive Medicine. The spirit of Rational Medicine cannot function, however, without material upon which to work. The basis, the elementary matter, as it were, of that material, is the conception we form of the nature of the bodily processes. Such a conception it is the function of Physiology to provide and to Physiology we therefore now turn.

§ 3. *The Transition to a Physiological Synthesis.*

Modern developments in physiological knowledge introduce an important period in the History of Medicine, for the study of the functions of the body is a natural portal of entry to the study of the perversions and suspensions of those functions that we call disease. The general character of physiological thought during the modern period may perhaps be described as the 'synthetic study of the animal body'. The study has become synthetic because organs have not been studied so much in and for themselves as in relation to other organs. There has been, in fact, during the period, an increasing consciousness of the integration of the organs into one organic whole, the entire process being under the control of the nervous system, the various parts of which are themselves integrated (p. 308). This movement has, to some extent, mitigated the ever growing evils of scientific specialization.

(a) *Anatomy and Embryology in the Earlier Nineteenth Century.*

Let us first glance at the state of anatomical knowledge in the early and middle nineteenth century. The general structure of the animal body was well known. Descriptive Anatomy was not far from where it now is. Comparative Anatomy, which had made good progress, was given a fresh impetus by the researches and by the authority of a brilliant group of French investigators, headed by Baron Georges Cuvier (1769–1832), whose influence spread to England, Germany, and America, where the leading exponents were Richard Owen (1804-92), Karl Gegenbaur (1826–1903), and E. D. Cope (1840–97). Cuvier was a biological dictator whose opinion did much to encourage investigation, and something to discourage some important investigators. His services to Comparative Anatomy can hardly be overrated. There was, however, still no effective knowledge of the anatomical differences between the races of man, while the species of man and of allied forms, whose skeletons palaeontologists have since described, were quite unknown.

As regards knowledge of the process of Development of the animal body, the broad lines of Embryology were being put on a firm basis by Karl Ernst von Baer (1792–1876), whose work was finished in 1837, though he lived another forty years. The subject was to be given a new meaning by the evolutionary school, which applied to new details and to particular instances the work of Charles Darwin (1809–82). Foremost of this school was Francis Maitland Balfour (1851–82).

(b) *Chemical Physiology in the Earlier Nineteenth Century.*

The analysis of the functions and workings of the body had advanced far less than the knowledge of its structure. The study of Respiration was perhaps in the best position. The elementary conception of Respiration attained by Lavoisier at the end of the eighteenth century (p. 155) was hardly extended till E. F. W. Pflüger of Bonn (1829–1910), in the sixties and seventies of the nineteenth century, showed that the essential chemical changes of respiration do not occur in the blood or in the lungs, but in the tissues.

A very important figure in the scientific world of the thirties and forties of the nineteenth century was the German Justus von Liebig (1803–73), professor of Chemistry at Giessen. He was a convinced mechanist, and over the door of the University Laboratory which he founded he had inscribed the dictum *God has ordered all His Creation by Weight and Measure.* His great achievement was his application of chemical knowledge to physiology. He did much to introduce laboratory teaching, and certain apparatus which he invented is still in constant use.

Liebig greatly improved the methods of organic analysis and notably he introduced a method for determining the amount of urea in a solution. This substance is found in human blood and urine, and was the first organic compound to be 'synthetized', that is to say, built up from inorganic materials. It is of very great physiological importance. This is due to the fact that it is regularly formed in the body in the process of breaking down the characteristic nitrogenous sub-

stances known as proteins. Along with his colleague, Friedrich Wöhler (1800–82), who had already synthetized urea, Liebig wrote a famous paper (1832) in which he showed, for the first time, that a complex organic group of atoms—or 'radicle' as it is called—is capable of forming an unchanging constituent through a long series of compounds, behaving throughout as though it were an element. The discovery is of primary importance for our conceptions of the chemical changes in the living body.

From 1838 onwards, Liebig devoted himself to attempting a chemical elucidation of living processes. In the course of his investigations he did pioneer work along many lines that have since become well recognized. He taught the true doctrine, then little recognized, that animal heat is the result of combustion, and is not 'innate' (compare p. 156). He classified articles of food with reference to the functions that he conceived they fulfilled in the animal economy. An outcome of this was his food for infants and his extract of meat. Very important was his teaching that plants derive the constituents of their food, their carbon and nitrogen, from the carbon dioxide and ammonia in the atmosphere, and that these compounds are returned by the plants to the atmosphere in the process of putrefaction. This discovery made possible a philosophical conception of a sort of 'circulation' in Nature. That which is broken down is constantly built up, to be later broken down again. Thus the wheel of Life goes on, the motor power being energy from without, derived ultimately from the heat of the sun.

It was very unfortunate that Liebig conceived and

adhered to a totally wrong view of the nature of putrefaction and fermentation, which it took Pasteur long years to display.

(c) *Nervous Physiology in the Earlier Nineteenth Century.*

From Chemical Physiology we turn to glance at the knowledge of the Nervous System. Charles Bell and his contemporaries (p. 145) had attained to a clear distinction of the nature of motor and sensory nerves and their separate origin from the two spinal roots (Fig. 98). The next fundamental contribution was made by Marshall Hall (1790–1857), who established the difference between volitional action and unconscious reflex (1833).

The fundamental ideas in the conception of reflex action had already been adumbrated by Descartes. In the view of that philosopher, any stimulus is transmitted along nerve-fibres to the central nervous system. There, on account of existing nervous connexions, it gives rise to a fresh impulse which passes along outgoing nerve-fibres to the active organ, muscle, or gland, which is thereby excited to activity (p. 128). Thus, every action of the organism, and its life as a whole, conforms to definite laws. These laws must be directed to its preservation, or organisms would cease to exist. It is thus possible to look on organisms simply as elaborate mechanisms. Except that we know that we ourselves think and feel, we might eliminate mind from our consideration of the action of beings other than ourselves. Such was the view taken by the mechanists and other members of the iatro-physical school (pp. 127–131), which followed, to a greater or less extent, the teaching of Descartes. The course of physiological advance

may be described, briefly, as the expulsion of the mental element from process after process associated with vital activity. This avenue leads on to a philosophical discussion whither we shall not now follow. It will suffice, at the moment, to remind the reader that only through the channel of *his own* thinking and feeling is he able to follow these physiological discussions at all.

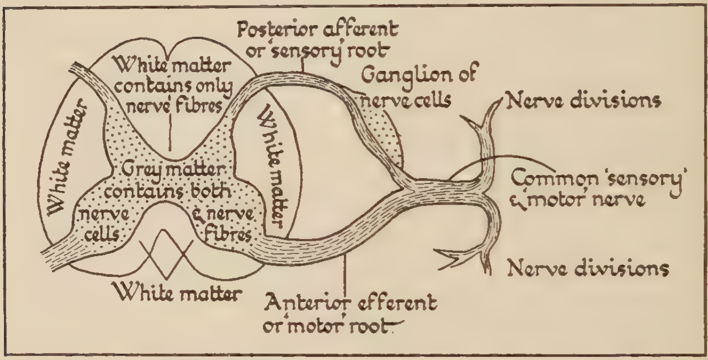


FIG. 98. DIAGRAM OF TRANSVERSE SECTION OF THE SPINAL CORD AND THE MAIN NERVES DERIVED FROM IT.

The conceptions of Descartes and of his successors were greatly extended by Marshall Hall. Interest was lent to Hall's work by the contemporary discovery by French observers of what was regarded as a special centre governing respiration—a very important reflex—in the lower part of the brain. Hall's work gave 'reflex action' a permanent place in Physiology.

Since Hall's time there has been a great extension of the conception of reflexes. It has been shown that, besides the simple nervous arc (Fig. 99), there are more complex nervous arcs which depend for their action on the integrity of an elaborate mechanism. The nervous

system is 'integrated' under higher and higher centres, till at last the highest centres of the brain are reached (pp. 308–11). Many of the ordinary acts of life, sneezing, coughing, standing, walking, even breathing, are expressible as reflexes. The attempt has also been made to press the 'instincts' into the same category. But it is difficult to separate the instinctive from the volitional

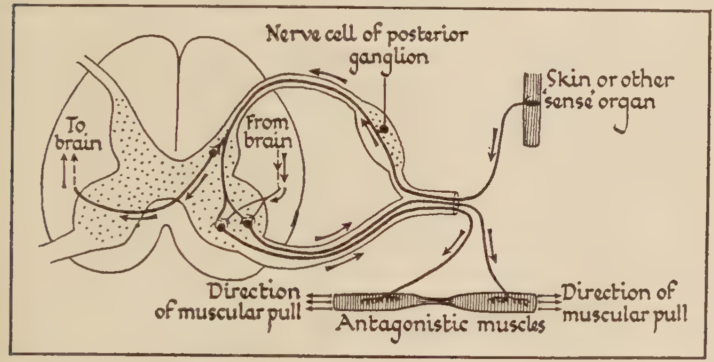


FIG. 99. DIAGRAM TO ILLUSTRATE SIMPLEST FORM OF REFLEX (cf. Fig. 98).

An afferent impression from a sense organ to the spinal cord may give rise to an efferent impulse by a purely intra-spinal process. This impulse may be of the nature of a complex and balanced muscular act involving a whole system of muscles, some of which may be antagonistic to each other. All this may take place not only unconsciously, without any intervention from the higher nerve centres in the brain, but even in an animal from which the brain has been removed. On the other hand, channels exist (and are indicated in the diagram) for passage of impressions to and impulses from higher centres. These higher centres in many cases control or modify the resulting muscular or other action to a greater or less degree.

elements or to define either. Vast, therefore, as is the development of this department of physiology, it is a very delicate task for the historian to pass any verdict upon it. The ultimate value of all this work must depend upon the conception that the next generation

attaches to the mental element in vital phenomena. There is evidence of reaction at the present time from the extreme mechanist physiological position.

Lastly, in the discussion of work on the nervous system comes the question of the localization of func-

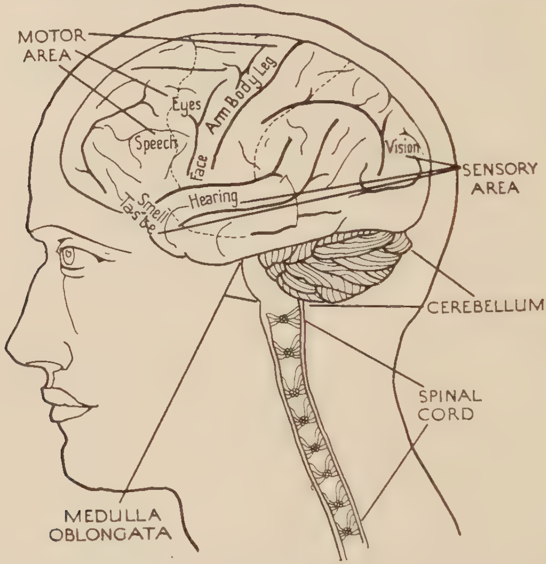


FIG. 100. DIAGRAM TO ILLUSTRATE SOME OF THE MAIN FACTS OF CEREBRAL LOCALIZATION.

tions of the brain. The possibility of such localization is a very ancient speculation. The idea was developed along rational lines, in the first third of the nineteenth century, by certain Viennese workers who, having made important contributions to science, unfortunately afterwards degenerated into phrenological quacks. Later several German observers began the study of the electrical excitation of those parts of the cortex of the

brain which specially control movement (Fig. 100). The work was continued and developed by a number of distinguished French and English observers, among whom Paul Broca (1824–80), Hughlings Jackson (1834-1911), and Sir David Ferrier (1843–) should be commemorated. Under their influence many operations usually regarded as involving complex mental processes, such as vision, speech, reading, writing, drawing, have been represented as depending on simple nervous relationships. Centres for the initiation of these operations have been described. Of late years, there has been reaction from this mechanical conception of the brain as an organ of the mind. The older school has, however, achieved clinical success especially at the hands of the great French physician Jean Marie Charcot (1825–93) and his pupils.

§ 4. *The Experimental Foundations of Modern Medicine.*

We may turn back to consider those who have been the immediate progenitors of modern Physiology. Among these, three men stand out beyond all others. In order of seniority, and perhaps of genius, they are Johannes Müller, Claude Bernard, and Karl Ludwig.

(a) *The Work of Johannes Müller.*

Johannes Müller (1801–58) was the greatest physiologist Germany has produced, and perhaps the greatest physiologist of all time. His genius was of the universal type and, despite his early death, he attained equal distinction in every department which he touched. Among these were Comparative Anatomy, Embryology, Physiological Chemistry, Psychology and Pathology. He was a careful scholar, well versed in the history of the

subjects which he taught, and as great a teacher as he was an investigator. A very large number of the best-known men who have advanced Medicine during the nineteenth century were his pupils while he was a professor at Berlin. His lovable character was pervaded by a mystical tendency.

Müller's text-book of Physiology began to appear in 1834. It introduced into the subject the comparative and psychological points of view, which were not fully appreciated until the generation that followed. The most remarkable generalization associated with his name—and one further developed by Ewald Hering (1834-1918)—is the 'Law of Specific Energies'. According to this law each sensory nerve, however stimulated, gives rise to its own specific sensation and to no other. Conversely, the same stimulus applied to different organs of sense produces a different sensation in each organ—that sensation, in fact, that is its specific attribute. Thus electrical, mechanical, thermal stimulation produce only the sensation of light when applied to the optic nerve. On the other hand, any particular form of stimulation, for example electrical, produces sensations of light, smell, hearing or taste if applied to the appropriate nerves.

A moment's reflection will enable the reader to realize the very great philosophical importance of these conclusions. They provide experimental evidence that the things of the external world are not in themselves discernible by us. Such external things we know only by the events to which they give rise acting on our senses, and yet from one and the same event utterly different sensations arise within us. To beings with senses different

from ours the world also would be different. The 'Law of Specific Energies' is thus fundamental for our view as to the range of validity of Scientific Method.

Among other important contributions of Johannes Müller to the physiology of the nervous system were his experimental confirmation of Bell's researches on the spinal roots (p. 145) and his experiments on the production of the voice. He launched important theories in explanation of colour vision, of the mechanism of hearing, and of the phenomena of fever. He was one of the first to use the microscope in pathology and he was one of the founders of Physiological Chemistry.

Like every investigator Müller made mistakes. In 1840 he stated that the velocity of a nervous impulse could never be measured. By 1852 his gifted pupil, Hermann von Helmholtz (1821–94), had measured it. Much of Helmholtz's work hardly comes within our department. He was, however, inventor of the instrument known as the *Ophthalmoscope*, by means of which the interior of the eye can be examined. This is the main factor which has enabled Ophthalmology to develop along true scientific lines (p. 319).

(b) *The Work of Claude Bernard.*

Claude Bernard (1813–78), the great French physiologist, was Müller's junior by twelve years and was in almost every respect a contrast to him. His mind was of that peculiarly French type to which anything mystical is abhorrent. He had few eminent pupils who owed much to him directly, but the influence of his ideas, through his writings, can hardly be exaggerated.

Especially Bernard was the founder of 'Experimental Medicine', that is of the artificial production of disease by chemical and physical means. This is one of the most important scientific movements within our field.

Bernard's great discovery, which occupied him for over ten years, was that the liver has the power of building up and storing certain highly complex substances, derived from the food and brought to it by the blood. The substances thus stored, and notably that known as *glycogen*, are distributed to the body according to its needs, in simplified and modified form. Now Wöhler in 1828 had synthetized urea (p. 206) and it was well recognized that this substance is a final degradation product which the body manufactures by breaking down the substances derived from food. It was also recognized that from this breaking-down process the bodily energy is obtained. Bernard showed that the body could build up complex chemical substances as well as break them down. This destroyed the conception, then still dominant, that the body could be regarded as a bundle of organs, each with its appropriate and separate functions. Bernard thus introduced what we may call a 'Physiological Synthesis', a conception of great import for the development of medical ideas.

No less important, and bearing on the synthetic view of the working of the animal body, was Bernard's work on the physiology of digestion. Up to the time of Bernard, an elementary knowledge of the facts of digestion in the stomach constituted the whole of digestive physiology. While Bernard was working on the glycogenic function of the liver, another worker had suggested that the secretion of the organ known as the

'pancreas', or sweetbread, emulsifies fats. Soon after, a German researcher showed that pancreatic juice acts on starch. Bernard now stepped in and cleared up the whole subject. He showed that digestion in the stomach is, as he described it, 'only a preparatory act'. He proceeded to demonstrate that the pancreatic juice, passing into the intestine, emulsifies the fatty food substances there and splits them up into fatty acids and glycerin. He further demonstrated the power of the pancreatic juice to convert starch into sugar, and he showed that it has a solvent action on such 'proteids' or organic nitrogenous substances as have not been dissolved in the stomach.

The third great achievement of Bernard was his exposition of how the blood-supply to the different parts of the body is regulated. This we now call the 'Vaso-Motor Mechanism'. In 1840 the existence of muscle-fibres in the coats of the smaller arteries was discovered. Bernard showed that the contraction and expansion of the 'arterioles' is associated with a complex nervous apparatus. The reactions of this apparatus depend upon a variety of circumstances in a variety of other organs; again an illustration of the close and complex interdependence of the various functions of the body upon each other.

(c) *The Work of Karl Ludwig.*

Karl Ludwig (1816–95) held a series of professorships at Marburg, Zürich, Vienna and Leipzig. He was, after Müller, the greatest of German physiological teachers, and he surpassed even Müller in the number of his pupils. As a physiologist he was chiefly remark-

able for his ingenuity as an inventor, for his wide and deep knowledge of the physical sciences and for his extreme generosity in handing over his work to his pupils.

Among the many lines of investigation of fundamental importance which Ludwig initiated, some of the most remarkable depended on the discovery of new methods. Just as the microscope had opened to the anatomist unexplored fields of research by bringing him into closer relation with objects which were hitherto beyond his scrutiny, so the rapid progress of physics and chemistry had placed more exact modes of observation and of measurement within reach of the physiologist. But the application of these methods was attended with great difficulty; there were no physiological laboratories, no instruments, no capable mechanicians to whom the physiologist could apply for assistance. Under such conditions, ingenuity and resource were indispensable to success, and in these qualities Ludwig was pre-eminent.

Accordingly, we find that two of the most important of the early investigations of Ludwig were as much due to his ingenuity as an inventor as to his clear grasp of the physiological questions which his inventions were intended to elucidate. The most interesting of these inventions, or rather adaptations, is the mechanically rotating drum or *kymograph*, as it is called. The word itself is derived from two Greek words which mean 'wave writer'. This instrument is now widely used, not only in Physiology but in every department of Science in which permanent records of any continuous movement are desired. The most familiar instance is the

self-recording barometer. The kymograph—the use of which had been suggested by Thomas Young (p. 319, and Fig. 101) in 1807—led to much wider applications

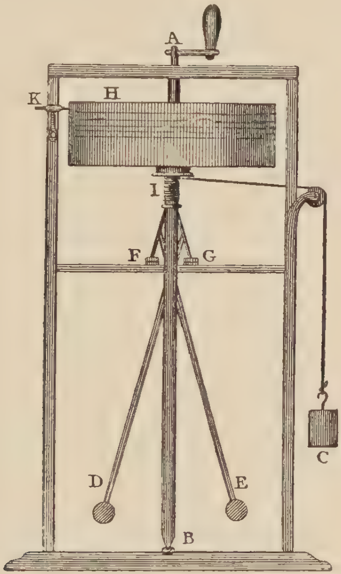


FIG. 101. THOMAS YOUNG'S KYMOGRAPH.

The cylinder H turns with the axis AB on which it is rigidly fixed. It is rotated by a handle at A which raises the weight C. When the weight is allowed to fall the cylinder rotates automatically. The rest of the apparatus is devised to secure constancy in rate of rotation. This was done by utilizing the effects of centrifugal force.

(As the rate of rotation increases the pendula D and E fly apart, they separate the weights F and G. These move with friction which increases as they separate, thus decreasing the rate of rotation.)

The movements of the pen at K are transferred into permanent graphic form by writing on the rotating cylinder H.

of the method of automatic record. Ludwig himself applied it to indicate the movements of respiration, as well as the variations in arterial pressure. Subsequently it

became further adapted to the 'graphic method', and it serves not only for the investigation of animal movements of every conceivable kind, but even for the transient and delicate electrical changes which are associated with vital action.

An instrument invented by Ludwig is the mercurial blood-pump, the purpose of which is to separate from a known quantity of blood, derived directly from the circulation, the mixture of gases which it yields to a vacuum. This is an indispensable apparatus for the investigation of the physiology of breathing.

Ludwig devoted much attention to the physiology of secretion. Here his work has been of great importance in connexion with the time-honoured discussion between the 'vitalists' and the 'mechanists'. He succeeded in showing that the process of secretion can be so transformed experimentally as to do external mechanical work. This was victory for the mechanist theory. The idea has since been applied to many structures.

It is impossible to attempt here any general summary of the conclusions reached by physiological research since Ludwig. Some have affected the actual practice of Medicine. Others are too recent or too little certain to have reacted in this manner. It is, however, safe to say that the more important conclusions of the three modern founders of the science, Müller, Bernard, and Ludwig, form the main scientific background of the clinical practice of our time. The results of the movement that they represent, together with the knowledge of the cellular structure of the body (§ 5, p. 219) and of the life-histories of the disease-causing organisms (§ 6,

p. 224), are the three main groups of ideas which separate the physician of our day from Laënnec (p. 161).

§ 5. *The Cell Theory and Cellular Pathology.*

During the process of the microscopic analysis of plants that took place in the seventeenth century a number of observers distinguished the walls of plant-cells and the word *cell* was introduced into the English language. Less clearly, a similar structure was discerned in animals. No real understanding of the nature of cells was, however, reached. Little farther progress was made in the eighteenth century, but just at its close a young French microscopist, Marie François Xavier Bichat (1771–1802), likened the microscopic structure of the animal body to the substance of a woven fabric. The word he used was the old French term *tissu*. He perceived that the different parts of the body, bones, muscles, nerves, blood-vessels, and the like, each presented a characteristic microscopic pattern. According to these appearances he analysed the parts of the body into twenty-one 'tissues'. Study of this kind came to be called 'Histology' (Greek *histos* = web).

During the seventeenth, eighteenth, and early nineteenth centuries, some advances were made in the knowledge of those organisms whose bodies are made up of only one cell, but their essential nature was still unappreciated. In the early nineteenth century a number of botanists and others were observing cells and cell contents. But no important advance in the interpretation of the appearances was made until the matter was taken up by Schleiden.

Matthias Jakob Schleiden (1804–81), professor at

Jena in 1838, put the matter in a new light. He noted, as had certain of his predecessors, the constant presence in every cell of the structure we now call the 'nucleus', and came to the conclusion that it is essential to the life of every cell. He reached the conception, moreover, that in a multicellular organism, such as a tree, every cell has a double life, one an essential and independent one, pertaining to its own development alone, the other an incidental and dependent one, in so far as it is an integral part of the plant. His work was somewhat vitiated by a fanciful conception of the origin of new cells.

The work of Schleiden was amplified and corrected in 1839 by Theodor Schwann (1810–82), a pupil of Müller. He showed that the tissues of animals, like those of plants, are susceptible of analysis into cells, and the difficulty of this process arises from the extreme modification of such cells as have developed for various special purposes. He showed too that the ovum or egg of animals is, in the first instance, a single cell, and that the cells of the body are derived and descended from it. He demonstrated that the entire animal or plant body is composed either of cells or of substances that are excreted or thrown off by cells. He gained some insight into the life of animal cells and in doing so he invented the very useful word *metabolic*. The word means 'liable to change'. It was used by Schwann, and is still habitually used in modern Medicine to indicate chemical changes within the body which are specially associated with living activity.

Contributions to the cell theory were made by other botanists. Hugo von Mohl of Tübingen (1805–72)

distinguished the contents of the vegetable cell just under the cell-wall from the watery sap that fills the

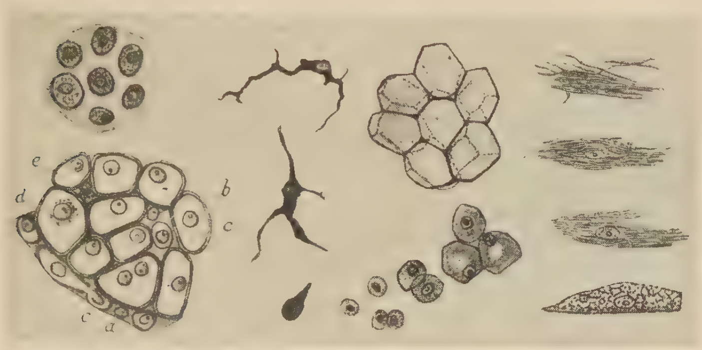


FIG. 102 FIG. 103 FIG. 104 FIG. 105

Drawings by Theodor Schwann to illustrate the nature and origin of animal cells. All are highly magnified.

FIG. 102. The first step in the origin of cartilage from cellular tissues. At the lower part the young cells are without cell-walls. In the upper part they have formed walls and are beginning to secrete cartilaginous substance. Nuclei and nucleoli are clearly visible.

Above is shown a piece of maturer cartilage, in which the cells are imbedded in a mass of cartilaginous material.

FIG. 103. Pigment cells, such as are characteristic of the skin of the frog. In the lowest cell, which is contracted, the nucleus is concealed by the pigment. The upper two are more expanded and in them nuclei can be seen.

FIGS. 104 & 105 show how structures of very diverse form can be differentiated from cells of the same type.

Fig. 104. Young cells from a developing feather. These cells may enlarge, secrete hard walls, and form the fine spongy tissue of the inner part of the shaft of the feather. Or the cells may elongate, the protoplasm become granular, and finally break up into fibres (Fig. 105). These form the tough fibrous matter of the outer part of the shaft of the feather. In either case, the nucleus disappears and the cell dies.

interior, introducing for it the term *protoplasm* (1846). The Swiss, Karl v. Nägeli (1817–91), by chemical

examination proved that protoplasm is nitrogenous and differs from other cell constituents (1862).

The cell theory was placed on a firm and clear footing by Max Schultze (1825–74), successor of Helmholtz (p. 213) as professor of Anatomy at Bonn. He defined the cell as 'a lump of nucleated protoplasm' (1861), introduced the idea of protoplasm as 'the physical basis of life', and showed that it presented essential similarities, physiological and structural, whether in plants or animals, and whether in higher or lower forms.

The study of tissues, Histology, was raised to the status of an independent science by the Swiss, Albrecht von Kölliker (1817–1905), pupil of Müller and professor at Würzburg, who wrote the first text-book on the subject (1850–52). Apart from this achievement, Kölliker is remarkable for having reached some of the conclusions in connexion with heredity that are associated with the name of Mendel, of whose work he knew nothing.

Even more influential on medical thought than Kölliker was Rudolf Virchow (1821–1902) of Berlin, one of the leading names in modern Medicine. There is indeed hardly any department of medical thought that has not gained something from Virchow's work. His great achievement is the way in which he carried the Cell Theory into the analysis of diseased tissues. In his *Cellular Pathology* (1858) he analyses diseased tissues from the point of view of cell formation and cell structure. Important sections of the science of Cellular Pathology have been explored so well by Virchow that they have been little extended by his successors. He initiated the familiar idea that the body may be re-

garded as 'a cell State in which every cell is a citizen'. Disease is often but a civil war. The white blood corpuscles, which have the power of engulfing and rendering innocuous bacteria and other foreign bodies, have been compared to police or scavengers. In some respects Virchow was strangely conservative, and notably he opposed the evolutionary view of the origin of living forms. Virchow's conceptions of the functions of the white blood corpuscles were largely extended by the Russian biologist Élie Metschnikoff (1845-1916) and the English worker Almroth Wright (1861–).

Since Virchow and Kölliker the study of the intimate structure and workings of the cells themselves, as distinct from the tissues, has become a separate and independent science under the name of *Cytology*. It may even be extended to the study of cells in disease as *Cyto-Pathology*.

Among the major developments of Cellular Pathology and Cyto-Pathology is the study of abnormal 'new growths'. The most malignant types of these belong to the group known as the 'Cancers'. The occurrence of most of these becomes more frequent as life advances (Fig. 135). Their cytological features are now well known. A cancer consists essentially of an increase of cellular tissue, following abnormally rapid multiplication of one type of cell. The new growth is equipped with a blood-supply which enables it to increase at the expense of other tissues and regardless of their needs.

Cancers almost always arise at one point, and are very seldom multiple in origin. It is fairly established that they are not infectious or contagious, and there is no

very satisfactory evidence that a tendency to them is inherited. Our scientific knowledge of Cancers is largely derived from animals. Cancers are 'specific' in the sense that those of one animal species will not grow when inoculated into another species. An immense amount of work has been done on inoculated Cancers, but it has become evident that some physiological factor is involved in Cancer incidence such that an inoculated Cancer is not entirely comparable with so-called 'spontaneous' Cancer. As to what that physiological factor can be we are still in the dark.

Although we know nothing effective as to this physiological factor, yet experiments in the artificial production of Cancer, apart from inoculation, have been attended with success. That various forms of chronic irritation are associated with the onset of Cancer has long been clinically recognized. It has been found possible to reproduce experimentally this relation between irritation and new growth, and so, for example, to induce Tar Cancer in mice. Nevertheless, it must be admitted that Cancer investigation is in an unsatisfactory state, and has yielded fewer positive results than any other department of Pathology of comparable importance. It is possible that we do not yet know enough of normal Cell Physiology to investigate with profit the forms of cellular perversion known as Cancer.

§ 6. *Establishment of the Doctrine of the Germ Origin of Disease.*

The view that many diseases, especially those of a contagious or infectious nature, originate from the

invasion of the body by special organisms and their multiplication within the body, came into prominence in the second half of the nineteenth century. There had been many previous adumbrations of this view and, in its final establishment, more than one hand may be discerned. Above all others who have worked in this field towers the mighty figure of Louis Pasteur (1822–95). We shall do no grave injustice to any man if we treat the scientific demonstration of the doctrine as the product of his superb genius.

The opening of Pasteur's interest in disease can be seen in his work on fermentation. At first he was faced with the opposition of Liebig. According to that eminent chemist, fermentation was not the result of vital activity but was a purely chemical change (p. 207). A ferment he regarded as an unstable organic product, the character of which determined the manner of decomposition of the medium in which it is placed. Pasteur demonstrated that, as there is a specific alcoholic ferment, so there is a specific milk-souring ferment. Any nitrogenous matter present in a fluid containing it will serve as food for the development of a ferment, but will not of itself induce fermentation. Ferments have, he demonstrated, the power of reproduction. Pasteur rapidly seized on the idea of the specificity of ferments. An albuminous sugar solution can be converted into various products by the addition of various ferments. According as one sows, so will one reap. The milk-souring ferment, Pasteur concluded, is organized and living, and its action is correlated to its development and organization. No life, no ferment; no ferment, no fermentation.

During the next years Pasteur applied himself to a study of ferments and notably of those which involve

FIG. 106. ORGANISMS OF FERMENTATION HIGHLY MAGNIFIED from Louis Pasteur's *Studies on Beer* of 1876.

1. Bacillus of Turned Wine. 2. Ferment of Soured Milk. 3. Butyric Ferment. 4. Ferment of Ropy Wine. 5. Ferment of Vinegar. 6. Amorphous deposit. 7. Sarcinae.

deterioration of wines and beers. This led him to perceive that there is a great multiplicity and variety of these organisms. Now it was an old and well-known

view that fermentation, putrefaction, and the infection of disease had much in common. It was perfectly natural, therefore, for Pasteur to regard the latter in the light of a vital process. A great difficulty was, however, the demand that any such doctrine made on the germ-bearing capacity of the air. Critics were not slow to avail themselves of this weakness, and pointed out that, according to Pasteur, the air must be one solid mass of germs! For the opponents of Pasteur the living organisms found in the process of fermentation or decomposition were the result, not the cause, of the process. These organisms were regarded by them as spontaneously generated in the fermentation process. Thus arose a discussion of the old theme of spontaneous generation.

By 1859—the year of publication of Darwin's *Origin of Species*—Pasteur was engaged in controversy as to the 'Origin of Life'. The discussion specially turned round what were then regarded as the lowest forms of life, the Bacteria. Were they ever spontaneously generated, or were they not? If a flask of broth, supposedly sterilized by boiling, went 'bad' and organisms appeared in it, was it certain that they had come from without, or could they have been spontaneously generated by the broth itself? Life must begin somewhere. Then why not here at this lowest stage? If this view be justifiable, Pasteur's doctrine of the nature of ferments must fall to the ground.

Pasteur had thus before him the task of proving a universal negative—a task impossible in Formal Logic. But Science is not Formal Logic. In the end he clinched the matter by an exquisitely simple experi-

ment which must, at once, carry conviction. A flask with a long S-shaped neck is filled with a putrescible fluid. It is heated to boiling, to kill all organisms, and then left in the still air of a room. Air can enter, but any floating germs that enter naturally fall on the floor of the S-shaped neck of the flask. Months may go by without any change in the liquid, but once the neck is

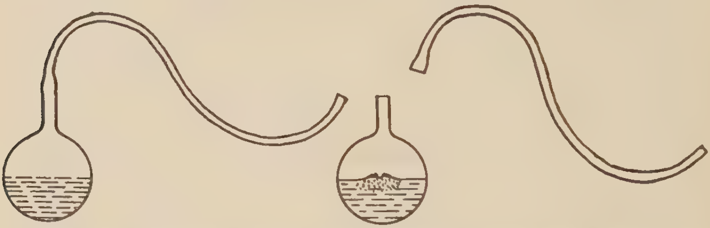


FIG. 107. PASTEUR'S CRUCIAL EXPERIMENT to prove that fermentation or putrefaction is the result of the action of air-borne organisms. The S-shaped flask contains a putrescible fluid such as meat broth. The flask containing the broth is subjected to prolonged heating to destroy all organism. It is then left in position with the mouth open. Days, weeks, months, even years, may pass without sign of putrefaction. No organisms reach the broth, since any that enter the open mouth fall on the floor of the neck and remain there. Sever the neck of the flask so that organisms can fall from the air directly on to the surface of the fluid and these multiply. In a few hours putrefaction sets in. This is shown by the formation of a film or scum on the surface just below the severed neck. Microscopically the broth is seen to be teeming with organisms.

severed, so that organisms can enter freely from the air, fermentation sets in within a few hours, and organisms can be detected in the liquid. Only living organisms from the air can have caused the change.

The first disease which Pasteur was able to demonstrate as causatively related to a living organism was a condition that was devastating the silkworm industry of France. In 1866 he proved the contagiousness of the disease, showed that it was due to a living organism,

and followed the organism through the life-history of moth, egg, worm, and chrysalis.

In 1870 the Franco-Prussian war broke out. Pasteur now decided to make investigations into the diseases of beer, his object being to improve the French brews and to carry the war into the enemy's camp by making them equal to the German! He succeeded in isolating special organisms, mostly yeasts, which produced defects in beer (Fig. 106). This work naturally led to an enlargement of his views on the nature and action of micro-organisms.

About this time Pasteur was elected a member of the French Academy of Medicine, a very unusual honour for one not a medical man. Lister had already begun his teaching, based partly on the work of Pasteur, and indeed his first important paper on antiseptic surgery had been published in the very year of the Franco-Prussian war. On entering the Academy Pasteur found himself faced by all kinds of ancient prejudices and misconceptions in connexion with his new doctrine, and especially with his denial of spontaneous generation. Among his supporters was the physiologist, Claude Bernard (p. 213). His work proceeded to more and more triumphant issues.

The first disease that affects man on which Pasteur was able to throw light was Anthrax, in relation to which his work interdigitates with that of Robert Koch and some other observers. Anthrax is a deadly and highly contagious condition which commonly affects cattle, but sometimes spreads to man. As early as 1855, a German observer had noted microscopic rod-like objects in the blood of beasts dead of the

disease. In 1868 an older French contemporary of Pasteur had shown that a bacillus is not simply the inseparable companion of the disease, but also is its cause and its only constantly acting cause. At this time the losses of cattle from Anthrax in France were enormous. The character of the outbreaks had been studied and seemed wholly unexplained by what was known of the bacillus. Farmers found that they lost cattle in fields from which infected animals had been excluded for months or even years. How was it to be explained?

The explanation was, in fact, advanced in 1876 by the German observer, Robert Koch of Berlin (1843–1910), whose work was now beginning. He showed that the anthrax bacilli under certain conditions formed 'spores', that is to say small encysted bodies, exceedingly resistant to heat and to other changes of external conditions (Fig. 108). This discovery opened up a new field which was cultivated by Koch and Pasteur and their followers.

While making his studies on ferments in 1863, Pasteur had witnessed the formation of spores in the organisms of butyric fermentation, but had failed to grasp their significance. In 1869 he had again found spores forming in the organisms of silk-worm disease, and had shown that they resisted prolonged drying. On the basis of their resistance he had explained the persistence and latency of the silk-worm disease. Other observers had had similar experiences. The investigations of none of them, however, approached in brilliance and completeness those of Koch.

Koch found that spores always form in the blood and tissues of animals dead of Anthrax, provided that

(1) the temperature is suitable, and (2) there is sufficient oxygen. These two conditions, temperature and oxygen, were found to be necessary. Below 18° Centigrade spores are not formed; at 30° Centigrade they occur at the end of thirty hours; at 35° Centigrade in twenty

FIG. 108. BACILLI OF ANTHRAX, from a culture, highly magnified.

The rod-like organisms are growing typically in chains. Some of the rods have white clear spots in them. These are the highly resistant 'spores'.

hours. The rapidity with which spores are formed is, therefore, proportional to the amount of heat. Oxygen was also found to be indispensable. Anthrax blood, if deprived of oxygen, ceases to be virulent in twenty-four hours without putrefaction. When the blood is allowed to putrefy the virulence also disappears if putrefaction exhausts the oxygen quickly enough to prevent the spores having time to form. If

the spores have already formed, putrefaction does not kill them, nor does it prevent them from developing later if circumstances become favourable. The persistence of the disease and its return in an infected country was thus explained. It was the spore which was the agent of preservation, which persisted where the conditions of temperature and of aeration had permitted it to form, and which always held itself in readiness to make new victims.

The matter was carried further by Pasteur in 1877. At that time he did not know of all the work of Koch. He succeeded in obtaining pure cultures of Anthrax. The question was then still being debated in France as to whether Anthrax was caused by a 'virus', that is to say a non-living poison, or by a microbe. Pasteur had long been a believer in the microbic theory, and it seemed to him probable that the blood of an animal infected with Anthrax, if sown in a suitable medium, would stock it solely with anthrax bacilli which he could then keep pure for an indefinite time in successive cultures, as he had done with yeast and other ferments.

Experiment proved this to be the case, and showed that the anthrax organism multiplied abundantly in urine made neutral or slightly alkaline. From that time the problem was solved. Take a series of cultures of the organism, transferring each time one drop from the preceding culture into 50 c.c. of fresh urine. The first dilution is 1/1000, the second one in a million, the third one in a thousand million. After ten cultures it falls to such a figure that the original drop of blood has been drowned in an ocean. Everything that it carried with it, to which we might attribute the produc-

tion of Anthrax—red corpuscles, white corpuscles, granules of all sorts—is either destroyed by the change of medium or is widely disseminated in this ocean and is lost. Only the organism can escape the dilution. Why? Because it has multiplied in each of the cultures. A drop from the last culture killed a rabbit or guinea-pig as surely as a drop of anthrax blood. It was, therefore, to the organism that the virulence belonged. A conclusion of the first rank was firmly established.

With a 'pure culture' of Anthrax in his possession Pasteur was able to experiment in a way which none had previously attempted. The most interesting stage of his work was now entered upon. He perceived that there are some species of animals which are refractory to Anthrax. Such are the birds. Nevertheless, the blood of a bird, when drawn from the animal, is an excellent culture medium for the bacterium. Why does it resist infection in the animal? Pasteur showed that the anthrax organism will not live in the bird because the living-blood in full circulation is filled with an infinite number of corpuscles which, in order to live and perform their physiological function, need free oxygen. When, therefore, the anthrax organism enters normal blood of living birds, it meets competitors ready to seize the oxygen for their own use. But the blood of other animals besides birds contains corpuscles eager for oxygen. Why can anthrax grow in them and not in birds? This question Pasteur answered by a convincing series of experiments (1878). The normal temperature of birds is higher than that of mammals and is, moreover, higher than that at which the growth of the anthrax organism is most vigorous. Thus the blood corpuscles

of the bird have the anthrax bacteria at a disadvantage. But if, by a cold bath, the temperature of a bird be lowered to that of a mammal, and if anthrax organisms be injected into the blood stream, they will grow and flourish at the expense of the bird.

The experiments with Anthrax on fowls led to experiments on the same creatures with another disease, the virulence of which was known to vary, Chicken Cholera. Thus arose naturally Pasteur's ideas and observations in the department of Immunity (p. 261).

If Pasteur can be said to have laid the foundations of the knowledge of the nature of infection, it is to Koch that we owe the main basis of the technique by which such diseases are now studied. He it was who elevated Bacteriology into the position of a separate science. Soon after his work on Anthrax he published a remarkable research which placed our knowledge of wound infection on a firm footing. He is thus among those who helped to create modern surgical technique. Many other communications came from him. None was of more far-reaching importance than his demonstration of the organism of Tuberculosis in 1882. All subsequent work in connexion with Consumption and allied conditions has been rendered possible only by this discovery of Koch. Other investigations associated with his name are on Cholera and on Sleeping Sickness. Koch was unquestionably the greatest bacteriologist that the world has seen. His genius was limited as compared to that of Pasteur, but his exquisite technical skill and acumen have never been excelled.

Since the time of Pasteur and Koch, the study of infectious disease has developed along various special

lines. The work of these two men, however, has determined the direction of those lines, and they themselves are the most typical, as well as the greatest, representatives of the most important of all movements in modern Medicine.

§ 7. *Anaesthesia.*

The aspect of surgical practice was dramatically changed during the course of the nineteenth century by two discoveries, that of Anaesthesia and that of the Antiseptic method. It will be convenient to consider Anaesthesia first.

There were from the earliest times many devices for producing more or less complete unconsciousness during surgical operations. An idea of the extremes to which surgeons at the beginning of the nineteenth century were put in this matter can be gathered from a glance at some of their devices (Fig. 108a).

The new era began in 1846 when the dentist, William Thomas Green Morton (1819–68), demonstrated at the Massachusetts General Hospital the simplicity and safety of Ether anaesthesia. The idea immediately caught on. Before the year was out Ether was being used for surgical purposes in England. In January, 1847, Sir James Young Simpson (1811–70) was using it in Edinburgh for obstetric purposes. A few months later he adopted Chloroform, which had been prepared by Liebig in 1832.

The use of the drugs spread very rapidly and almost as rapidly changed the character of surgical technique. Until the adoption of anaesthesia, speed was of primary importance in surgical procedure. Excessive speed

now became a matter of less importance, and operative neatness and completeness took its place as the chief quality of good surgery. Moreover, operations of a more drastic character could be undertaken since the shock to the patient was minimized. Women in labour were found to bear Chloroform peculiarly well and safely, and its use in midwifery steadily spread despite some foolish and fanatical opposition.

Soon after the introduction of anaesthetics efforts were made by various methods to secure a painless state

FIG. 108a. SCREW adapted to the lower limb, as used by surgeons in the eighteenth century and the early nineteenth century, to compress the nerves in order to secure analgesia during amputation. Its application, however, was extremely painful in itself and injurious to the part operated on.

of a part without involving unconsciousness. The first successes were obtained in 1884 at Vienna with applications of solutions of the alkaloid (p. 325) Cocaine, first to the eye, then to the nose and other parts. Cocaine, or some derivative of it, has ever since been much used in Medicine. It was soon being given by injection under the skin for small superficial operations. Next, good results from injecting solutions of it into the nerves were obtained by several American surgeons, earliest of whom was W. S. Halsted (1852–). His work of 1885 was extended in 1898 by Harvey Cushing (1869–). Yet another American surgeon, J. L. Corning (1855–), introduced the method of so-called 'spinal anaesthesia'. This is secured by injecting a

solution of Cocaine or one of its derivatives into the spinal canal and thereby inducing insensibility to pain ('analgesia') below the site of injection. In 1908 the American G. W. Crile (1864–) introduced a valuable method of combining local and general anaesthesia, whereby he minimized the effects of 'shock' (pp. 310–11) during the progress of the operation.

From first to last almost all the pioneer work upon anaesthetics and analgesics has been of American origin. Even the word *anaesthesia* is an American invention. It was introduced or at least familiarized by Oliver Wendell Holmes (1809–94), the distinguished and brilliant author of the 'Breakfast Table' series. Laughing Gas was first applied to dental purposes a short time before Ether was given its surgical application, and its introduction for this purpose was the work of the American dentist Horace Wells (1815–45), of Hartford, Connecticut.

§ 8. *The Revolution in Surgery.*

The history of antiseptic surgery is inseparably linked with the name of Lord Lister (1827–1912), whose work naturally dovetails into that of Pasteur. Lister's attention was first called to the work of Pasteur in 1865. But Pasteur's views on the life of micro-organisms came to a mind that had been prepared for them. Lister had had, moreover, a long and varied surgical experience and had been present at the first operation performed in England under ether anaesthesia in 1846.

At that time and for long after, Surgery was cursed by the constant fear of sepsis. A vast amount of death

and suffering was due to this cause, and surgeons were reluctant to perform many operations that we should now regard as trivial. Lister's first attempt to make any scientific analysis of the septic state is to be found in a paper by him on *The Early Stages of Inflammation* (1853). He showed that the effects of irritation on the tissues are twofold. Firstly, there is a dilatation of the arteries which is developed through the nervous system. Secondly, there is an alteration in the tissues on which the irritant acts directly. This alteration imparted, as Lister thought, an adhesiveness to both the red and the white corpuscles, making them prone to stick to one another and to the walls of the vessels, and so giving rise to stagnation of blood and ultimately to obstruction.

Some years before (1847) A. V. Waller (1816–1870), a pupil of Magendie, had shown that during the process of inflammation there is an active migration of white blood corpuscles through the walls of the capillary blood-vessels. Waller's observations attracted but little attention at the time. They were, however, amply confirmed in 1878 and the following years by the German pathologist Julius Cohnheim (1839–84), a pupil of Virchow. Cohnheim showed that this process of migration of white blood corpuscles is the essence of inflammation and that when inflammation goes on to suppuration the pus that is formed consists largely of white blood corpuscles in a dead and disintegrating state.

Irritation, and the reaction of the body against it, 'inflammation', are encountered in all injuries in which the healing is not direct and healthy. It was those cases of injury in which the healing was indirect and un-

healthy which then formed the surgeon's chief problem. Of these there are a variety, now rare, then very common and fatal, as Blood Poisoning, Erysipelas, Pyaemia, Septicaemia, Hospital Gangrene, and that form, then so common as to be almost normal, simple suppuration of a wound.

About 1861 Lister began to teach publicly that the occurrence of suppuration in a wound is determined 'simply by the influence of decomposition'. The nature of decomposition was revealed to him by the writings of Pasteur. From him he learned that putrefaction was, in fact, a fermentation, and that it was caused by the growth of minute microscopic organisms borne by the air. It was generally supposed that air was the cause of sepsis, and precautions were taken to exclude it from wounds. But Lister now saw that not air but that which it carried was the mischief-maker.

The general course of action was now clear to him. As a laboratory proposition the destruction of the organisms of the air was simple. The problem was to exclude them from wounds during and after operation. The solution of that problem developed as 'Antiseptic Surgery', which later became 'Aseptic Surgery'. At first he paid most attention to air, as the source of infection. He recognized, however, that he must also deal with the germs present in the wound and on his hands. Of the methods available for ridding the air of its germs, viz. heat, filtration, and chemical action, he chose the last.

At that time carbolic acid was in use as a means of treating sewage. At first, therefore, Lister tried lint soaked in crude carbolic. This he found liable to cause superficial sloughing and death of the tissues. He next

obtained a purer acid, using a solution in oil. A putty formed of common whitening and a solution of carbolic acid in linseed oil was used as a dressing. He adopted later a system of spraying the part during operation (Fig. 109).

When Lister began his work, amputation of a limb was a very fatal operation. Yet it had to be performed in most cases of severe fracture in which the bone was exposed because, without it, death from sepsis was almost certain. The improvement in Lister's own records of amputation, incident upon his adoption of the antiseptic method, is well brought out by his own figures:

Years.	*No. of Cases.*	*Recovered.*	*Died.*	*Mortality.*
1864–6	35	19	16	43% without antiseptics
1867–70	40	34	6	15% with antiseptics

These results were considered extraordinarily good in their day. It is an index of the further advance since Lister's first attempts that results ten times as good would now be regarded as unsatisfactory. Moreover not only has the further development of Lister's method rendered amputation safer, but also it has enabled the surgeon to treat many cases without amputation, when before he would have been compelled to resort to that measure.

Lister first recorded his observations on the antiseptic system of surgery in 1867. Apart from the technical advances that he then set forth, he recorded also many new pathological facts that have since proved of great practical importance. Thus he showed that an uninfected clot, if undisturbed, can become organized into a living tissue, and that a piece of dead bone may be absorbed in an aseptic wound. These are now

matters of common knowledge, but then they were instrumental in introducing a radically new outlook.

Lister gradually perfected his technique, chiefly in the direction of using milder antiseptics and adopting heat for the sterilization of instruments and dressings.

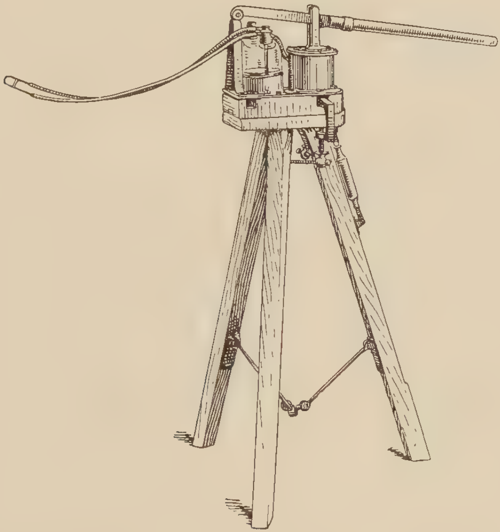


FIG. 109. THE 'DONKEY ENGINE', an apparatus designed and used by Lord Lister to maintain a carbolic spray over a part during operation. The engine is worked by the up and down movement of the handle to the right and the spray is delivered through the tube to the left.

The antiseptic system was given its military application in France during the war of 1870. It was soon taken up also by German surgeons. The history of surgery since Lister's day has been very often told. An important element in it is the gradual supersession of 'antiseptic' by 'aseptic' methods (p. 248).

The Listerian system, in rendering surgery safer,

had also the effect of opening up many fields of operation that had previously been regarded as impracticable. Especially is this the case with abdominal surgery, which effectively dates from the introduction of the

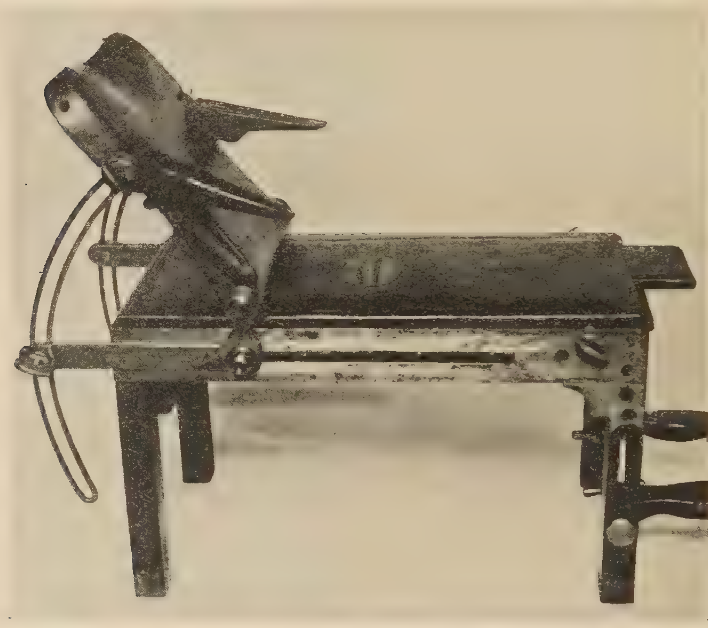


FIG. 109 A. OPERATING TABLE USED BY LORD LISTER in the Glasgow Royal Infirmary.

antiseptic system. Lister was often misunderstood and some of his contemporaries, and some even of those who opposed him, were really practising his system without knowing it.

Among the most important reactions of antiseptic surgery was that upon the conduct of labour. Here Lister had a predecessor, as he gladly and generously

acknowledged. This was the unfortunate and almost insane Viennese genius, Ignaz Semmelweis (1818–65). At the great lying-in hospital at Vienna in which he was an assistant the death-rate at one time rose to thirty per cent., the so-called 'puerperal fever' being the active cause. The women were attended by students or physicians who were visiting the post-mortem room. Semmelweis showed that the infective material that conveyed the fever was brought by the hands of the operator from the dead bodies and he showed that puerperal fever was caused by decomposed animal matter. By insisting on the hands of the operators being sterilized, Semmelweis succeeded in 1846 in enormously reducing the mortality. After the acceptance of Lister's antiseptic system the methods of Semmelweis were universally introduced into the practice of Midwifery. Another predecessor of Lister was Oliver Wendell Holmes. As early as 1843 he pointed out that the mysterious 'puerperal fever' was contagious, and carried by the hands of the operator. He suggested precautions not dissimilar to those of Semmelweis.

§ 9. *Some Modern Surgical Advances.*

Among the most capable surgeons of Lister's own day was Thomas Spencer Wells (1818–97) of London. This great operator had been opening the abdomen successfully for certain conditions since 1858. By 1867 his methods were approaching the Listerian. Under Lister's inspiration he further improved his technique and did more than any other man to raise the possibilities of abdominal surgery. Spencer Wells stands out for the extreme simplicity, directness, and effective-

ness of his methods (Fig. 111), and for his exceptionally conscientious care as an operator. His name is commonly attached to an instrument of his invention for catching the bleeding ends of cut blood-vessels. The familiar 'Spencer Wells forceps' is at this day probably more frequently used than any other surgical instrument (Fig. 110).

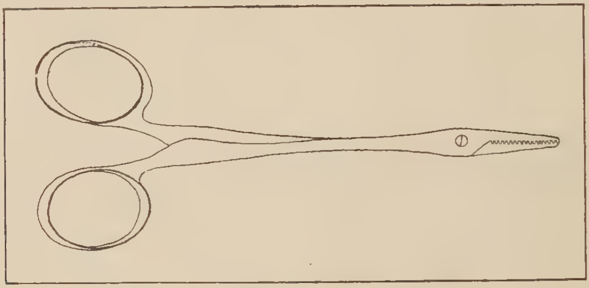


FIG. 110. 'SPENCER WELLS FORCEPS.'

Since the time of Lister many branches of Science have contributed to the development of surgical technique. No addition to the surgical armoury has, however, been more important than that made by the physicist Wilhelm Conrad Röntgen (1845–1923). In 1895 he found that when an electric discharge passes through a high vacuum rays are emitted that are far more penetrating than ordinary light. These rays have since then been placed in series with light rays, ultraviolet rays and infra-red rays, and it has been shown that they differ from these only in their wave-length. The surgical application of the Röntgen or X-rays was at once made to the examination of bone. Since then the more accurate knowledge of the properties of these

rays has made them of value in exploring almost every organ of the body. Radiography is now constantly applied in the diagnosis of medical and surgical conditions of the organs of the chest and abdomen.

The more dramatic achievements of modern surgery,

FIG. 111. SPENCER WELLS performing an abdominal operation about 1870. The picture illustrates the extreme simplicity of the methods of this great surgeon. It also shows a method of administering chloroform. Air is pumped through a bottle into a mask held at a variable distance from the face of the patient.

the drastic operations that surgeons are now able to perform on the great cavities of the body—head, chest, and abdomen—have attracted much public attention. Nevertheless few surgical advances have relieved so much suffering and disability as the unsensational development in the treatment of fractures.

After the advent of Listerian methods the technique of the treatment of compound fractures was gradually perfected. Simple fractures—which are far commoner—continued, however, to be treated with splints in the

FIG. 112. AN OPERATION IN THE SIXTEENTH CENTURY.

The semi-conscious patient lies face downward on an elaborately carved bed. The bearded surgeon, dressed in his ordinary clothes, is trephining his skull and is rotating the trephine between his hands. Against the side of the bed lounges a gallant to whom a servant brings refreshment. In the background are two women assistants. A male assistant is spreading a plaster and another warming a towel over a brazier. Note that all present, surgeon, nurses, assistants, &c., wear their ordinary dress. No arrangements are made for washing. In the foreground is a cat playing with a mouse.

traditional fashion. Plaster of Paris bandages, which came into wide use in the 'seventies, were some improvement; but prolonged immobilization of a limb, in either splints or plaster bandages, always involves much subsequent pain and stiffness, lasting, at best, for

months. To obviate this, Massage—a practice of immemorial antiquity in Folk Medicine—had been introduced into Surgery in the sixteenth century by Ambroise Paré (pp. 92–94). The subject was little heard of till the

FIG. 113. AN ABDOMINAL OPERATION UNDER MODERN CONDITIONS

Only those directly concerned with the operation are present in the room. All wear aseptic clothes and aseptic rubber gloves. Every source of infection is guarded against and all breathe through masks. The patient is covered by aseptic cloths and only the part operated on is exposed.

last thirty years of the nineteenth century. The pioneer was the Dutch surgeon Johann Mezger (1839–1900), through whom some scientific advance was made.

The introduction of X-rays into Surgery made for

very accurate diagnosis of the state of fractures. It has thus gradually become possible to treat a large proportion of these injuries without immobilization either by splints or plaster. In many cases the injured limb is merely held in correct position between sandbags and massage used from the first. Much stiffness and disability is thereby avoided and the length of the period of treatment greatly shortened. The rise of a class of scientifically trained Masseurs has made possible a wider application of this valuable curative procedure.

Improvements in methods of operation have been very numerous during the last generation. Many can be appreciated only by those with technical knowledge. In 1886 Ernst von Bergmann of Berlin (1836–1907) introduced steam sterilization of dressings and thus moved toward the replacement of antiseptic by aseptic methods. W. S. Halsted, then of New York, had been working to the same end. In 1890, finding it impossible to sterilize the hands completely, he introduced the rubber gloves now universally employed by surgeons during operations. Much important work in experimental surgery has been done by Alexis Carrel of New York (1873–) and some of his laboratory methods have become available in surgical practice. The technique of abdominal surgery has been greatly advanced by many workers, important among whom are J. B. Murphy (1857–1916) of Chicago and the brothers Charles and William Mayo (1865 and 1861) of Rochester, Minnesota. The surgery of the brain was prosecuted in England by Rickman Godlee (1849–1925), the nephew and biographer of Lister, by Victor Horsley (1857–1916), and above all by William Macewen

(1848–1926), a successor to Lister's chair at Glasgow and one of the finest exponents of Listerian methods. The surgery of the nervous system in general, and that of the brain in particular, has been carried to extraordinary refinements in America by Harvey Cushing. There can be no doubt that during the twentieth century advances in Surgery have been more important and more numerous in the United States than in any other country.

§ 10. *Bacteriology becomes a special Science.*

We have seen the microbic view of the origin of disease demonstrated as a reality by Pasteur (pp. 224–35) and extended to special disease conditions by him and by Koch (pp. 229–32). While the French observer stood above all men for the clearness and steadiness of his vision and for his persistence and resource in following what he had seen from afar, his German colleague had a genius for visualizing particulars and for adapting mechanical devices and scientific discoveries to particular ends. Koch thus vastly improved and elaborated the methods for detecting and examining minute organisms. The significance of his results was at once recognized, but the complexity of the technique involved and the time and training necessary demanded the elevation of the subject into the position of a special science.

Though but fifty years old, the science of Bacteriology has itself undergone repeated subdivision. Noteworthy though the results of this process of constant subdivision have proved, it must be emphasized that the state of scientific subdivision cannot be final, and

is indeed without meaning unless it lead to a subsequent synthesis—an event which we still await. It is the general Laws reached by these special sciences that are philosophically important, and the specialist himself is often ill-placed and ill-equipped for the estimation of the true significance of such Laws. The philosophic thinker who deals with generalities and centuries must often be content to pass the details in silence. Nor is this true only of the professed philosopher. It applies no less to the philosophical physician. It is his task to try to see life steadily and see it whole. He must think both in terms of the individual life and of the community life, and for him the results of the bacteriologist, the physiologist, and of all their colleagues are as means to an end. It is from this standpoint that we should seek to visualize the fruits that bacteriological science in this last age has laid at the feet of humanity.

With Koch's work on Anthrax in 1876, on the bacteria that commonly infect wounds in 1878, and with his great discovery of the bacillus of Tuberculosis in 1882, the study of the infective diseases entered on a new stage. The enemy had been seen and was now known for what he was. The bacteriologist had succeeded in making prisoners. These had been isolated and made to live in test-tubes. Moreover, the organisms had been compelled to dwell alone without mixing with other species. They had been obtained, as bacteriologists say, in 'pure cultures', and delicate methods of detecting and differentiating them had been developed. With a pure culture in his hands, the bacteriologist can determine the influences favourable or unfavourable to the growth of the disease organism,

and he can investigate conditions that can exalt, destroy, or modify its activity (p. 233).

An important series of criteria established by Koch have remained the tests by which the disease-bearing character of these organisms can be established. To prove that an organism is the inseparable cause of any disease we need to demonstrate:

1. The constant presence of the organism in every case of the disease.

2. The preparation of a pure culture, which must be maintained for repeated generations.

3. The reproduction of the disease in animals by means of a pure culture removed by several generations from the organisms first obtained.

These conditions have been fulfilled for many diseases. Evidently the third test can be applied only in conditions to which animals other than man are susceptible. Now in this matter the organisms that produce disease vary greatly. Some, for instance those of Anthrax, are easily conveyed to a variety of species of animals; others, for instance those of Syphilis, are with difficulty conveyed to very few species of animal; yet others, for instance human Malaria, cannot be conveyed to any animal save man.

Some light is thrown on the life-history of the second and third classes by recent discoveries. The science of Comparative Pathology, that is the knowledge of the relations of the diseases of different species of animals, is of very recent growth. It has already demonstrated, however, the existence of organisms bearing some resemblance, for instance, to those of human Syphilis and human Malaria as the cause of disease in animals. By

studying the life-history of these organisms in animals and by studying their effect on animals, valuable side-lights have often been thrown on the allied diseases in man. Moreover, in exceptional cases and in some special diseases, it has been possible to convey a disease experimentally to man.

A second important factor has gradually come into prominence with the extension of bacteriological knowledge. It is evident that not all men are subject to all human diseases. Even in the most destructive epidemic there are some that escape. These lucky ones may be naturally 'immune'. Many diseases, such as Measles, seldom recur in individuals who have been infected, so our lucky ones may thus have an 'Acquired Immunity'.

The general nature of Immunity we shall presently discuss (p. 259), but we note here that Immunity may be relative or absolute, and may, moreover, vary according to the circumstances of the individual. Thus, for instance, a well-fed, well-housed person of temperate habits, living an open-air life, is unlikely to develop consumption. Restrict his diet, confine him in an office, deteriorate his mode of life, and he may well fall a victim to it. The investigation of facts such as these on a large scale has demonstrated that the *soil* in which disease grows is of no less import than the *seed* from which it grows. The problem of disease causation is thus immensely complex. We are only just beginning to draw up general laws on the subject, and in approaching it we are beyond the frontiers of our positive knowledge. Turned back from this difficult borderland, we must content ourselves with surveying

a part of the better-known territory and considering a few specific bacteriological achievements. These we may now consider under the headings of the diseases associated with them.

§ 11. *Some Important Bacteriological Results.*

Diphtheria is a disease for which physicians now habitually demand a bacteriological diagnosis. Bretonneau of Tours (p. 185), working on clinical and post-mortem material, and without the use of a microscope, was able to distinguish Diphtheria as a specific disease (1826). Half a century later (1883) Edwin Klebs (1834–1913) of Zürich, a pupil of Virchow, described the specific organism of the disease. In the following year Friedrich Loeffler (1852–1915), a Prussian and an assistant of Koch, succeeded in cultivating it. The organism has since been known as the 'Klebs-Loeffler Bacillus'. Its study has thrown much light on the nature of bacterial action in general and has, moreover, led to important therapeutic developments (p. 263).

Of all diseases destructive of human life, none is so dramatic as *Plague*, the scourge of mankind throughout history. The bacillus of Plague was discovered independently by the Japanese Shibasaburo Kitasato (*c.* 1860–), a pupil of Koch, and by the Frenchman Alexandre Yersin (1863–), a pupil of Pasteur, during an epidemic at Hong Kong in 1894. These two observers cultivated the organism and reproduced the disease by inoculation of pure cultures in animals. It had long been observed that outbreaks of a deadly disease of rats and mice were liable to precede Human Plague. These 'epizootics' which precede 'epidemics'

are now known to be due to the bacillus of Plague. A mass of evidence has been collected to show that the normal carrier of the Plague infection is the rat flea. This knowledge has led to the formulation of effective measures for the control of Plague. These measures are

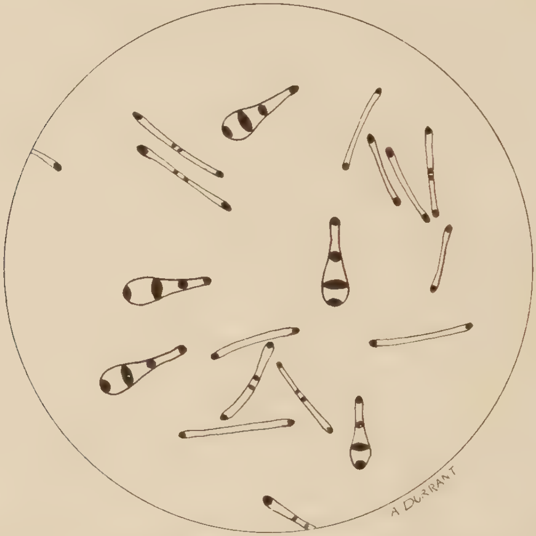


FIG. 114. BACILLI OF DIPHTHERIA FROM A CULTURE. Highly magnified. In cultures these bacilli are liable to degenerate into thick club-shaped forms several of which are here seen.

based on the wholesale extermination of the rat population which harbours the infective fleas. The study of the Natural History of the Plague Bacillus has also led to prophylactic measures for the safety of individuals.

Malta Fever is a disease of much wider distribution than its name implies. Not only is it found throughout the Mediterranean area, but it is also encountered in China, South Africa, and parts of both North and South

America. It is a long, tedious and wearing disease, and though the mortality from it is low, yet it was at one time one of the main causes of disability in the British army at Malta. In 1887 an English military surgeon, David Bruce (1855–), succeeded in cultivating

FIG. 115. BACILLI OF PLAGUE FROM A CULTURE. Highly magnified.

a characteristic bacillus from the spleen of a patient dead of the disease, and he established its causal relation to Malta Fever. In 1904 its mode of propagation was studied by a British Government Commission. The goat was shown to be the normal host of the bacillus, and in Malta 50 per cent. of these animals were found to be infected. The disease, it was discovered, is usually transmitted by goat's milk. The knowledge has led to the application of very effective precautions (Fig. 116).

Among the most anciently described diseases is the condition known as *Tetanus* or 'Lock-jaw'. There are

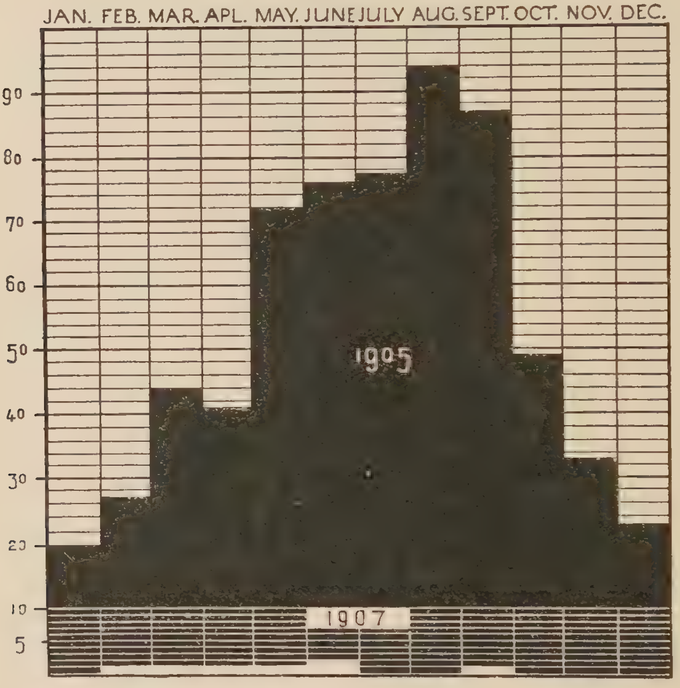


FIG. 116. DIAGRAM SHOWING THE INCIDENCE OF MALTA FEVER in the British garrison at Malta immediately before and immediately after the institution of the preventive measure of cutting off the supply of unboiled goats' milk. The figures of 1905—before the new regulation came into force—are represented in black. The figures in the margin refer to the number of cases per ten thousand of strength. The figures for 1907 are represented in white on the same scale. There is a drop in the maximum monthly incidence from 94 to 2. The size of the garrison itself remained almost constant throughout the period.

unmistakable references to it in the *Hippocratic Collection* and notably in the *Aphorisms*. Two of these

references we have already quoted (p. 23). A general association of Tetanus with wounds has long been recognized. In the eighties the disease was shown to be transmissible from animal to animal. It was, moreover, experimentally produced in animals by the inoculation

FIG. 117. BACILLI OF TETANUS FROM A CULTURE. Highly magnified. The drum-stick forms are very typical.

into them of garden mould. In 1889 Koch's pupil, Kitasato, obtained the Bacillus of Tetanus in pure culture and conveyed the disease to animals. He found the organism would grow only in the absence of Oxygen. It is, in fact, a type of a large and now well-known group, the 'anaerobic' bacteria. The natural habitat of the Tetanus Bacillus has been proved to be soil, and especially richly manured soil. The knowledge of the

bacillus, of its habitat, and of its mode of growth has led to the development of a valuable protective process.

Looking backward from the standpoint of present-day knowledge we can trace *Typhoid Fever* far back

FIG. 118. BACILLI OF TYPHOID FEVER FROM A CULTURE. Highly magnified. The long flagellae, which are constantly in motion and are very characteristic of these organisms, are well seen.

in history. Nevertheless, it was not till 1837 that the distinction between the two distinct conditions known now as 'Typhoid' and 'Typhus' was first clearly made. This was the work of an American physician, William Gerhard (1809-72), of Philadelphia. The English were backward in adopting the distinction. The organic cause of Typhoid Fever was first seen in 1880 by Karl Joseph Eberth (1835–1927), a pupil of Virchow, and

after him it is known as 'Eberth's Bacillus'. It was not isolated, however, until some years later. It is an inhabitant of the intestine, and its natural history was obscured by confusion with certain other and very similar organisms, which also dwell in the intestine. These have now been fairly differentiated from each other, and in the course of this process the 'flora', both normal and pathological, of the intestinal canal has become well known. Moreover, it has been shown that typhoid organisms are not always of the same species, but that several closely allied forms produce several closely allied diseases. Lastly, certain of the effects wrought by the typhoid group of organisms on the body, which is their host, have been exactly investigated. These investigations have led to improved methods of recognition of the disease, that is to say, *diagnosis*, and also of prevention of its incidence, that is to say, *prophylaxis*. To these methods of diagnosis and of prophylaxis we now turn.

§ 12. *The Study of Immunity.*

In the production of disease by living organisms two main factors are involved. There is, firstly, the multiplication of the organisms themselves, and there is, secondly, the production by the organisms of poisonous substances or *toxins*. The former phenomena are spoken of as *infection*, the results of the latter come under the title of *intoxication* or *toxic* effects. The first toxins to be investigated were those isolated from putrefying substance and named *ptomaines* (1876, by false formation from Greek *ptoma* 'a corpse'). These are, in fact, definite chemical substances of the group known to chemists

as 'alkaloids' (p. 325). Later, toxins were prepared from actual disease organisms such as those of Typhoid and Tetanus (1888). The method was introduced of filtering the bacteria away from their fluid cultures and thus obtaining a bacterium-free liquid containing the poisonous bacterial products. This was the starting-point of the scientific study of toxins. These, it soon became clear, were either substances which were normally sent out by the bacteria, *exotoxins*, or they were normally retained within the bacteria and could only be obtained in solution by breaking up the bodies of the bacteria, *endotoxins*. The use of these toxins has been essential for the scientific study of Immunity.

The word *Immunity* is derived from a Latin word which means 'exemption from military service'. In Medicine it indicates an exemption, relative or absolute, from the incidence of a disease. Immunity in the medical sense is of various kinds. There is 'species immunity', some species not being liable to diseases to which others fall victims. There is relative and there is absolute immunity. There is innate and acquired immunity. Of acquired immunity there is a natural immunity resulting from the ordinary contraction of a disease, and there is an 'artificial immunity'. It is only artificial immunity that is in the hands of the physician.

Artificial immunity itself is of two kinds, and both kinds are of use and of importance in Medicine. There is an *Active Immunity*, which is produced directly by injection of disease organisms or their products. It is found, however, that if a high degree of active immunity be attained the blood-serum of the immunized

animal, when injected into a second animal, may itself produce a state of immunity. The state thus indirectly produced is described as *Passive Immunity.*

The early observers found that when organisms are cultivated outside the body they lose their virulence to a greater or less degree. Pasteur found this for Chicken Cholera (p. 234). He found, moreover, that such 'attenuated cultures', when inoculated, protect against the disease. By the use of attenuated cultures he succeeded in establishing a state of 'Active Immunity' against Chicken Cholera. But there are many other ways of attenuating the virulence of an organism. Thus, in 1882, Pasteur showed that to grow Anthrax bacilli at a high temperature would reduce their virulence. These bacilli of reduced virulence could be injected into a sheep. They would give the animal the disease in a mild form and protect it against further attacks of the disease. They acted, in fact, in the same way as did the old 'Inoculation' of Small Pox (p. 183).

It has been found, however, that the same kind of immunity which is produced by administering attenuated cultures is sometimes given even by dead cultures. Nearly all active immunization is therefore done by inoculating such killed cultures. These are usually called 'Vaccines' from the analogy which they bear to vaccination. The most familiar and effective 'vaccine' is that against Typhoid. Moreover, it has been found that in certain cases the principle of the induction of Active Immunity may be applied directly in the treatment of disease. The conditions that respond best to this line of treatment are those which present some localized infection, such as a boil or carbuncle. In such

cases we must suppose that, while the local capacity for resistance is lowered, yet reserves of resistance in other parts of the body can be brought into play. These reserves are called up by the signal that reaches them by the reaction of the body against the Vaccine.

It has been shown that, for the production of Active Immunity, the actual bodies of the disease organisms are not always necessary. In some cases, toxins obtained from these disease organisms are themselves sufficient to induce Active Immunity. The matter may become of great medical importance in the future and is already applied for Diphtheria (p. 265).

We turn to 'Passive Immunity'. The fact that Immunity can be transferred from one animal to another via the serum proves that the immunizing serum contains substances antagonistic to the bacterium or toxin against which immunity is conveyed. These antagonistic substances are spoken of as *Antibodies*. A series of very important observations on Antibodies has been made, and may in time profoundly modify not only our views of Disease but also our whole conception of the workings of the living body. We find that it is not only toxins that stimulate the formation of antibodies. Antibodies can be elicited also by the introduction into the tissues of the living body of red blood corpuscles, of embryonic tissue, and of various soluble tissue-constituents of animal or vegetable origin. We are still only on the threshold of the investigation of this subject, which may be as important philosophically as it is therapeutically.

§ 13. *Some Practical Applications of Immunity.*

We may now consider a few special applications of our knowledge of the defences against bacterial action.

Diphtheria is a disease in which the characteristic organisms are found only locally, and in artificially

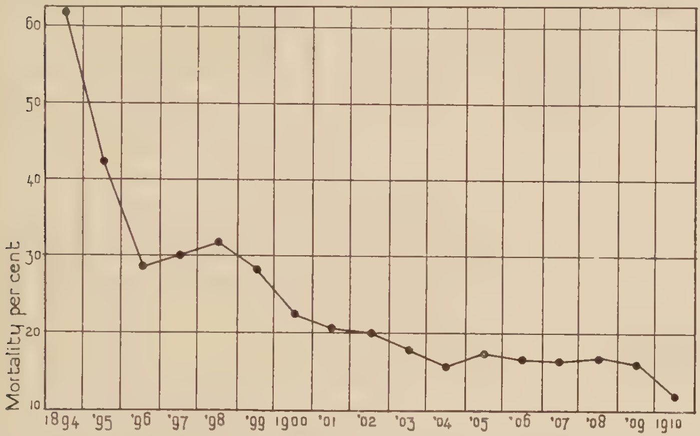


FIG. 119. DEATH-RATE OF CASES OF LARYNGEAL DIPHTHERIA IN PUBLIC HOSPITALS IN LONDON. Antitoxic serum came into use in London in 1895 and into full use in 1896. As its application became more general and as the method of administration improved the death-rate from this very grave condition progressively fell.

produced cases only at the site of inoculation. It therefore seemed probable from the first that the symptoms were due not to the organisms themselves but to poisons that they threw off, that is to their 'exotoxins'. This was given demonstrational form in 1889 by two pupils of Pasteur, Pierre Roux (1853–) and Alexandre Yersin (1863–), who investigated many of the properties of these toxins. In the following year (1890)

Emil von Behring (1854–1917), a Prussian Army Surgeon, and Kitasato showed that it was possible to produce a Passive Immunity against Tetanus by a serum from an infected animal, the immunity being efficient against 300 times the fatal dose of Tetanus. Their paper contains for the first time the word *antitoxic*. Immediately after, von Behring showed that against Diphtheria, too, immunity could be obtained by injecting serum from an animal that had been previously injected with living cultures of the Diphtheria bacillus. This epoch-making discovery of von Behring was soon given a practical application. It was found possible to induce a degree of immunity even after the onset of the disease. The first human case was a child in a clinic at Berlin in 1891. Antidiphtheritic serum was placed on the market in 1892. In a few years' time its administration had become a routine part of the treatment of the disease. Diphtheria antitoxin is one of the greatest additions to therapeutics. With competent administration the case mortality of Diphtheria is one-half or one-quarter of what it is without the use of Antidiphtheritic serum. (Fig. 119.)

An important aspect of the reaction of the body to the Diphtheria toxin was revealed by B. Schick of Vienna in 1908. The technique of inducing it was perfected by him in 1913, and the test is known by his name. He showed that susceptibility to the disease could be detected by the behaviour of the skin after injection of minute doses into it. It has thus been found that new-born infants are seldom susceptible and that the proportion of susceptibles increases up to two years of age, but that then it diminishes. The actual propor-

tions of susceptibles, as estimated in a large number of cases in New York City in 1919, are as follows:

Of those under	3 months	15%	are susceptible
Of those between 3 months and	6 months	30%	are susceptible
Of those between 6 months and	1 year	60%	are susceptible
Of those between 1 year and	2 years	70%	are susceptible
Of those between 2 years and	3 years	60%	are susceptible
Of those between 3 years and	5 years	40%	are susceptible
Of those between 5 years and	10 years	30%	are susceptible
Of those between 10 years and	20 years	20%	are susceptible
Of those over	20 years	15%	are susceptible

These figures show why Diphtheria is mainly a disease of childhood and is relatively seldom encountered in adults. They also make it evident that steps for protecting individuals against contracting the disease—'prophylactic measures' as they are called—need only be taken with a fraction of the population. The useful term *Prophylaxis* is derived from a Greek word meaning a watchman or guard. It is used to describe preventive measures against disease in general, but is more specially applied to that form of protection which is achieved through the artificial production of Immunity.

Such prophylactic measures are now available against Diphtheria. They differ from those in use against any other disease, since the substance injected is neither the living infective material as in vaccination against Small-pox (p. 184), nor is it a killed culture of the organisms as in immunization against Typhoid (p. 268), nor is it the serum of an immunized animal as in the protective measures against Tetanus (p. 267). The Toxin itself (mixed with an experimentally determined proportion of its antitoxin) is now in wide and effective use as a

prophylactic against Diphtheria. The method was proposed by von Behring (cp. p. 264) in 1913. The details, however, have since been worked out in the laboratories of the New York City Department of Public Health and have been mainly the work of W. H. Park (1863–). The susceptibles are first determined by the Schick test and are then immunized against the disease. The immunization reduces the likelihood of contracting the disease to about one quarter.

Plague differs from Diphtheria in that the organisms, instead of being local, pullulate throughout the body of the victim. As in the case of most diseases of this type, the toxins of Plague are chiefly *endotoxins*, unlike those of Diphtheria, which are *exotoxins* (p. 263). Thus, the filtrate of a culture of Plague Bacilli is but little toxic and confers little or no immunity. Protective vaccines of a killed culture of Plague Bacilli are, however, prepared, and these confer considerable immunity. It is claimed that they reduce the liability to the disease by about three-quarters, and the case mortality by about one-half. Prophylactic inoculation against Plague is associated especially with the name of the Russian investigator Waldemar Haffkine (1860–), a pupil of Pasteur, who was for many years in the service of the British Government in India, the Plague centre of the world.

After Diphtheria one of the earliest diseases of which the toxins were investigated was *Tetanus*. Kitasato found in 1891 that the filtrates of pure cultures injected into animals are very toxic. A peculiar feature is the incubation period of some days that occurs between the inoculation and the advent of the symptoms. This fact had been referred to, more than two thousand years

earlier, in the *Aphorisms* of Hippocrates (p. 23). Moreover, it has been found that, soon after inoculation, the Tetanus toxin disappears from the blood-stream. This, it has been shown, is due to its affinity for nervous tissue, with which it rapidly enters into some sort of combination. The fact is of clinical significance and of therapeutic application.

By injection of small and progressively increasing doses of Tetanus toxin into animals, a high and long-lasting degree of immunity to the disease is produced. The serum of such immunized animals has the capacity to protect animals susceptible to the disease against an injection of a fatal dose. It is now a routine treatment to inject serum derived from an immunized horse into those who have wounds likely to result in Tetanus. Owing to the rapid disappearance of the Tetanus toxin from the blood-stream, and owing to its tendency to unite with nervous tissue, it is important to inject the serum as soon as possible after the infliction of the wound. In some cases it is advisable to inject the serum into the sheath that surrounds the spinal cord in order to give it as rapid access to the nervous centres as possible. During the Great War prophylactic doses of Antitetanic Serum were given to every wounded man after 1914. Before the practice was adopted, the incidence of Tetanus among the wounded was 16 per 1,000. After the introduction of this line of treatment as a routine, the incidence fell to 2 per 1,000. Countless lives were thus saved. Antitetanic serum should be injected as early as possible in every case of a large ragged wound, especially if contaminated with soil.

Typhoid Fever differs from Diphtheria, Plague, and

Tetanus in that it can hardly be conveyed to animals. It has thus proved impracticable to produce anything in the way of passive immunity in man. On the other hand, there is no disease in which the production of active immunity by means of Vaccines of dead cultures has been attended with more favourable results. The researches which led up to the introduction of active immunization against Typhoid Fever are bound up with investigations concerning the diagnosis of the disease which are of wide importance in connexion with several other diseases.

The discovery of Antibodies (p. 262) gave rise to great activity in their investigation. Among the most interesting and important of the antibodies is a group which will cause 'agglutination' or clumping of the disease organisms with which they are specially associated. This reaction is specific for the corresponding organisms, within certain limitations. Given, therefore, (1) a pure culture of an organism, and (2) the knowledge of the highest degree of dilution of the serum containing such an antibody that will cause agglutination of that particular organism, the physician has in his hands a means of detecting or excluding infection with that organism. The method was especially studied by the Parisian investigator Fernand Widal (1862–), who in 1896 succeeded in making it practicable for Typhoid Fever, and his name is attached to the test. It is now universally applied in that disease. Similar tests have been devised for Malta Fever and for other conditions.

There are other groups of antibodies that have been investigated. Some of these possess the power of dissolving the corresponding organism. They are, there-

fore, known as *Bacteriolysins*. Their existence gives a certain insight into the defensive mechanism of the animal body against bacterial invasion. They are sometimes of practical use in distinguishing types of disease-producing bacteria. The method is applicable, for example, in detecting certain types of dysentery organisms.

Another group of antibodies act not against bacteria but against certain specific substances. Antibodies of this type were first detected by the Belgian workers Jules Bordet (1870–) and Octave Gengou (1875–) in the year 1900. The physician avails himself of the existence of such an antibody in the test that is applied for Syphilis, which was introduced in 1904 by Ehrlich's pupil, August von Wassermann (1866–), and is known by his name.

Of late years a special aspect of Immunity has come into view in connexion with the so-called 'Carrier Problem'. With many diseases, acquisition of Immunity on the part of the patient implies the death within his body of the organism that has been causing the disease. There are conditions, however, in which the organisms may lurk in some individuals long after the symptoms have subsided. These persons may even contract the disease so lightly that they are unconscious of it, but nevertheless they become capable of conveying it. Such individuals are known as *carriers*. Evidently the existence of carriers introduces special difficulty into attempts to delimit an infective disease in any population.

Among the diseases of known bacterial origin that are sometimes conveyed by carriers are Typhoid Fever, Diphtheria, and Spotted Fever or Cerebrospinal Menin-

gitis. A special case of the Carrier Problem is afforded by Infantile Paralysis, a disease due to 'ultra-microscopic' organism—since the virus is 'filtrable' (p. 274). This disease, like that of Cerebrospinal Meningitis, is probably transmitted by carriers who do not themselves suffer.

Typhoid Fever, Diphtheria, Influenza, Scarlet Fever, and many other conditions are often conveyed by 'ambulant' cases. This term is applied to those cases which, while definitely suffering from a disease, do not regard themselves as ill enough to take to their beds but continue their ordinary avocations. Such ambulant cases are not less but more dangerous to their neighbours than those more severely stricken.

The whole study of the Carrier Problem is in its infancy. It is beset with extraordinary difficulties. In the case of Diphtheria and Typhoid Fever, however, the demonstration that a suspected individual is or is not a 'carrier' is easy. The difficulty is to trace him in the first instance!

§ 14. *The Conquest of the Tropics.*

Nowhere in Medicine has the rational spirit been more triumphantly vindicated than in connexion with the diseases peculiar to hot countries. The increase in the habitability of the Tropics may be traced to two main causes. First is the application of the ordinary laws of Hygiene. Second is the increasingly exact knowledge of the microbic origin of tropical diseases, leading to a more complete apprehension and a stricter application of the laws of Hygiene.

We have glanced at the great changes wrought in

the social organization of temperate countries by the rise of modern Hygiene (pp. 172–78), which commenced to be felt about the middle of the eighteenth century. The death-rate then began to fall, and has fallen steadily ever since. The mid-eighteenth century marks, for temperate countries, the end of the 'Middle Ages' of Hygiene. But with the advent of the modern period the fall in the death-rate in temperate countries has not been the only change in the public health. Even more significant is a change in the *causes* of death.

Certain diseases have gradually receded from the more civilized and settled temperate countries, and are now almost unknown there. Thus, Malaria, Plague, Typhus, Leprosy and Dysentery, once of world-wide distribution, have come to be regarded as more or less distinctively 'tropical' diseases. A time is approaching when we shall be able to place other diseases with which temperate countries are still afflicted, such as Typhoid Fever, in the same category. The ultimate exclusion of Typhoid as a disease of civilized communities is suggested by the death-rates of England and Wales.

Average Annual Death-rate in England and Wales from Typhoid per million living.

1871–80	1881–90	1891–1900	1901–10	1911–20	1921–26
332	198	174	91	35	24

In the category of such removable diseases which, being excluded from temperate countries, are regarded as tropical are Malaria, Plague, Typhus, Leprosy, and certain forms of Dysentery. These diseases are 'tropical' only in the sense that it is in the Tropics that the general hygienic conditions most favourable to their

development are still found. If the hygienic conditions of the Tropics could be raised to those of the civilized temperate countries—a task, it is true, of very great difficulty—these particular diseases might become as rare there as they are with us. Indeed, it is possible to foresee a world in which a number of these so-called tropical diseases will have disappeared altogether.

FIG. 120. A common Malaria-carrying mosquito × 3.
FIG. 121. The Yellow Fever-carrying mosquito × 3.

There are, however, other diseases that are tropical in another sense. Such diseases have seldom or never visited the shores of temperate countries, or at least have obtained no lasting foothold there, even when the conditions have been favourable to them. Among such diseases are Yellow Fever, Sleeping Sickness (which must not be confused with the so-called 'Sleepy Sickness'), Beri-Beri, Dengue, Sprue, Kalar-azar, and a host of other less known conditions.

It must be said, to avoid misunderstanding, that 'the

Tropics' in the medical sense is a region considerably wider and far less well-defined than the geographical Tropics. Moreover, despite the existence of diseases peculiar to the Tropics, 'tropical diseases' form no natural group based on any common organic causation. The organisms that give rise to the various 'tropical diseases' differ from one another just as much as the organisms that give rise to the diseases of temperate countries.

Since we cannot speak of tropical diseases on the basis of their common causation, we are forced to deal with them as separate entities and especially from the point of view of their prevention. We will therefore select two diseases, the history of which illustrates the process by which the Tropics have been rendered safer both for European and for native races. These will serve as types, and we will choose one from the truly tropical group which does not invade temperate climes, and the other from the group which is being gradually excluded from temperate climes. No better instances of these two groups can be adduced than Yellow Fever and Malaria.

(a) *Yellow Fever.*

In discussing the history of Yellow Fever, as of many other conditions, it is perhaps best to begin at the end, for modern knowledge of the organic cause of a disease often illumines and gives a meaning to historical records.

In 1918 the Japanese investigator Noguchi observed a very delicate and minute spiral organism in the blood of a case of Yellow Fever at Guayaquil, the principal port of Ecuador, on the West Coast of South America,

one of the most important endemic centres of the disease. Noguchi showed that guinea-pigs inoculated with the blood of this infected case developed symptoms similar to those of Yellow Fever, and he was able to demonstrate the same organism in the sick guinea-pigs. He passed the disease by means of inoculation from one guinea-pig to another. He succeeded in obtaining pure cultures of the organism on artificial media. He passed such cultures through a series of guinea-pigs and finally recovered it in pure culture again. He showed that different strains vary greatly in virulence, a fact in accord with the great variability in the gravity of attacks of Yellow Fever.

One of the reasons why the discovery of this organism has been so long delayed is doubtless the very small numbers in the blood of patients suffering from Yellow Fever. Thus, the toxins must be extremely powerful. Indeed, it has been shown that 1/10,000 of a cubic centimetre of a virulent culture rapidly induces fatal symptoms in a guinea-pig.

There are other important points about the Yellow Fever organism. It passes through a stage in which it is so small as to be beyond the reach even of microscopic vision. This fact is known because the blood of a Yellow Fever patient is infective when passed through any but the finest filters. The organism in fact exists in what is called a 'Filter-Passing' stage. Of late years a number of infective diseases have been shown to be due to filter-passing organisms of this type. Among them is the organism of the disease known as Infantile Paralysis (p. 270). The study of 'filter-passers' bids fair to be in itself a special science.

Finally, Noguchi threw light on the nature of Yellow Fever epidemics. He was able to pass the parasite from one guinea-pig to another, not only by inoculation in the ordinary way, but also by means of the bite of a species of mosquito which has long been known to be the carrier of the disease for man. He showed that a period of some twelve days' duration within the body of the insect is necessary for the parasite again to develop its dangerous phase. The period of incubation in man, that is, the time that passes between the infective insect bite and the appearance of the disease, is 3–5 days, but 12–14 days is the period that usually elapses after the introduction of a case of the disease before other cases occur. The discrepancy is now explained. The disease is not infectious except through the mosquito, so the developmental period of the parasite within the mosquito corresponds to the incubation period of the epidemic.

Outbreaks of Yellow Fever have struck the public imagination, have given rise to folk tales and have inspired poets. The story of the *Flying Dutchman* is that of a ship stricken with Yellow Fever. The spectre ship is supposed by sailors to haunt the seas around the Cape of Good Hope, and to bode ill for those who see it. A murder was committed on the ship, and following it 'Yellow Jack' broke out. All ports were closed to the wretched crew, who finally all died of the disease. The *Flying Dutchman* was the subject of an opera by Wagner and a novel by Marryat. A picture of a ship smitten by Yellow Jack is to be found in Coleridge's *Ancient Mariner*.

An historic case may be quoted. In 1837 a barque

named *Huskisson* was at Sierra Leone. She was lading when Yellow Fever appeared among the crew. All but two or three died. Yellow Fever broke out in the colony, but gradually died down. The *Huskisson*, in the meantime, remained in harbour without hands for three months. At last, hands were obtained, tempted by very high pay. Again the Yellow Fever broke out among them and again nearly all died. They were bitten by infected mosquitoes which remained in the ship during the three months. Many cases, no less dramatic, are on record. The disease is among those which are peculiarly common and fatal among medical men. Thus, Senegal has twice been denuded of medical men by Yellow Fever. In 1830 six died out of twelve, and in 1878 twenty-two out of twenty-seven.

An attack of Yellow Fever confers Immunity. In children it assumes a mild form, and therefore, in countries where the disease is endemic, the population consists largely of the survivors of attacks. On this account terrible outbreaks of the *Flying Dutchman* or *Ancient Mariner* type are always either on immigrant ships or in places which have remained long unvisited by the disease, in other words such outbreaks occur under conditions in which immune persons are few or absent.

The distribution of the Yellow Fever mosquito is wider than the distribution of Yellow Fever at the present day, but Yellow Fever is never found, save in sporadic outbreaks, where the mosquito cannot live permanently. The distribution of the mosquito corresponds, however, to the areas where the disease has in the past, from time to time, established itself, but is

smaller than the area wherein sporadic outbreaks have been reported.

During the seventeenth and eighteenth and even the nineteenth century there were repeated outbreaks of Yellow Fever far beyond the region to which it is now confined. Along the eastern shores of North America it has at times extended as far north as New York, and there have been destructive outbreaks in Baltimore, Philadelphia, and even Boston. The disease has been found along most of the littoral of South America. In the Old World it has visited chiefly West Africa, where it was imported very early by the slave trade. It has visited at times Spain, Portugal, and Italy with devastating epidemics, and has even occasionally made a call in France and once in England. The last considerable outbreak in Europe was at Madrid in 1878.

England has always had important interests in the West Indies. During the eighteenth and first half of the nineteenth century she had, moreover, large military establishments there, which were regarded as very bad stations. In Thackeray's *Vanity Fair*, which refers to the period just after the Napoleonic wars, the disreputable and unfortunate Rawdon Crawley is sent as governor to 'Coventry Island' in the West Indies, and is not expected to last long! There are many historic occasions on which the British forces in the West Indies lost almost incredible numbers from Yellow Jack, garrisons being practically wiped out. In Jamaica the mean annual mortality in the garrison was for many years 185 per 1,000! In the Bermudas the mortality was about 80 per 1,000. One should remember that soldiers are picked men in the prime of life, and that these

mortality rates were in places now regarded as health resorts! A hundred years ago, Jamaica had the highest death-rate in the Empire, with the exception of West Africa, where the mean annual mortality of whites at Sierra Leone was 362 per 1,000!

Conditions in the West Indies began to improve definitely from about 1850 onwards. At that time there was no effective knowledge of the organic cause of Yellow Fever, nor, for that matter, of any other tropical disease. Only lately has the basic reason for this early improvement become obvious. From about 1850 onwards the water-supply in the more settled parts of the West Indies, and notably in the larger towns, came to be arranged by pipes. Now these towns were the special resorts of the Yellow Fever mosquito. The removal of open standing water, the enclosure of water-supplies, and the introduction of ordinary modern sanitation in the clearing away of rubbish, did good work without any knowledge of the organic cause of the disease.

We now know the life-course of the Yellow Fever mosquito. We know her breeding habits and how the water-living larvae congregate specially in the small collections of water in the neighbourhood of houses. Precautions have been taken against them and under favourable circumstances the disease has completely disappeared in well-managed districts under British and American control. The romantic story of the destruction of Yellow Fever in the Panama zone, in Cuba, Puerto Rico, Jamaica, Barbadoes, Trinidad, New Orleans, has been too often recited to be detailed again. Every one has heard of the tragic event in connexion

with the American Mosquito Commission of 1900 and of the death of Lazear. He and his colleagues, led by Walter Reed (1851–1902), finally proved that the disease is never conveyed by bedding, or by clothes, or by other objects, but always and only, in nature, by the bite of an infected mosquito.

During the experiments of the American Commission, cases of Yellow Fever were produced in volunteers by bites of infected mosquitoes, by injection of blood of infected patients, and by injection of *filtered* blood serum of infected patients (p. 74). With this knowledge in his hands, the American chief sanitary officer of Havana, William C. Gorgas (1854–1920), began to destroy mosquitoes systematically and to treat all Yellow Fever patients under mosquito nets. Within three months Havana was free from Yellow Fever for the first time for one hundred and fifty years. These wonderful results are brought out by a table:

Deaths in Havana from Yellow Fever.

Year.	*Deaths.*	*Year.*	*Deaths.*
1885	165	1895	553
1886	161	1896	1,282
1887	532	1897	858
1888	468	1898	136
1889	303	1899	103
1890	308	1900	310
1891	356	1901	18
1892	357	1902	0
1893	496	1903	0
1894	382	1904	0

Except for the semi-civilized states of Central and South America, Yellow Fever is now generally under control. It is perhaps not always realized, however, that, while the local extinction of this disease may be

among the future triumphs of modern science, its substantial control over large areas is part of the history of world hygiene (p. 278), and that it is part of the very same movement that has made our own cities healthier and more habitable than they were in the Middle Ages.

(b) *Malaria.*

The history of Malaria, which is also carried by a mosquito, is very different from that of Yellow Fever. Malaria was, till recent times, a disease of temperate as well as of tropical countries. The old name for the disease is *Ague*. The word *Malaria* is of no great antiquity in the English language. It came into use only in the eighteenth century. Like the word *Influenza*, it is of Italian origin, and, like *Influenza*, it carries with it a forgotten pathological theory. *Malaria* is simply *mala aria*, that is, 'bad air'. So *Influenza* is *the influence*, that is to say, the influence of unpropitious planets or comets that were held to rain down poison into the air. It was believed that these diseases were the result of local atmospheric conditions. In Rome and the Campagna the natives still believe that just as the sun goes down the air becomes specially poisonous.

While the *term* Malaria is comparatively modern, nevertheless, recognizable accounts of the *condition* are perhaps more ancient than those of any other disease. Of all diseases produced by micro-organisms, Malaria has perhaps changed its type least during the course of historic time. The disease is distinctly described in several places in the *Hippocratic Collection*.

The conception of diseases as separate entities is, of course, modern. In the case of most infectious

diseases, therefore, we cannot hope to follow the history very far back. But the symptoms associated with a malarial attack are so definite that there is no difficulty in tracing the disease with certainty as far back as

Fig. 122. Geographical Distribution of Indigenous Malaria in England and Wales about 1860.

1000 B.C. The real division into ancient and modern times comes, for this disease, with the use of Cinchona, which is the plant from which Quinine (p. 326) is now derived. Very soon after the introduction of Cinchona in the seventeenth century, fevers came to be habitually divided into those which respond to Cinchona and those which do not. Cinchona—and therefore its derivative,

Quinine—is one of the drugs that we owe to the discovery of the New World (p. 95). The rind of the Cinchona tree was taken as a remedy by the aborigines. In Europe, where it was introduced by Jesuit missionaries, it became known as 'Jesuits' bark'. It was popularized by Sydenham (p. 100) and has ever since been widely used in medicine.

Sydenham gave a good description of Malaria. During the seventeenth and eighteenth centuries epidemic after epidemic of 'Ague' swept over England as over other European countries. These epidemics spread from their endemic centres, the low-lying, ill-drained, swampy districts, where the Malaria mosquito could breed freely in the slowly flowing water. Of such places the principal in England were the Fens of Cambridgeshire, Lincolnshire, and the surrounding counties, the marshes on either side of the estuary of the Thames in Kent and Essex, the marshes of Romney and Pevensey on the South coast, and those around Bridgewater near the Bristol Channel (Fig. 122). There Malaria was never absent, though it differed greatly in prevalence and severity in different years. Ague remained prevalent in London as late as 1859. The proportion of ague cases to the total number of in- and out-patients at St. Thomas's Hospital in London from 1850–60 varied from between 12 per 1,000 at lowest to over 60 per 1,000 at highest. Thus, over one-twentieth of the patients in a large London hospital suffered from what we now regard as a tropical disease, within the lifetime of men who are still with us!

In London the rise in the value of land led to the erection of the Thames Embankment, which effectually

reclaimed the land around the river. Extensive works of drainage were at the same time being undertaken in other infested districts. These soon had their now well-known effect. In 1864 Malaria was found to be rapidly diminishing everywhere, and to have left many of its old haunts. The disease retreated rapidly. At the beginning of the twentieth century a systematic search was made for a native case in England. After much labour one single case was at last found. It may safely be prophesied that native Malaria will never again be anything but a rare disease in any temperate country with an efficient sanitary service.

The story of the discovery of the malarial parasite is worth recounting. These organisms inhabit the red blood corpuscles and were first seen by Alphonse Laveran (1845–) in 1880 in Algiers. His observations were extended by French and Italian observers, who showed that the sudden rise in temperature in Malaria coincides with a process of division of the parasite. Later the suggestion that the parasite might be conveyed to man by the mosquito was made by Patrick Manson (1844–1922). The matter was clinched in 1898 by Ronald Ross (1857–), who showed that the malarial parasite necessarily passes through a stage in the stomach of the mosquito. The process was first traced by Ross in a malarial parasite that is peculiar to certain birds, and was subsequently demonstrated for the allied species of parasite that produces human Malaria.

We have here an illustration of the value of comparative pathological studies. Since the demonstration of the life-cycles of the malarial parasites of man (Fig. 123), the chief attention of hygienists interested in

Description of Fig. 123.

The life-histories of the parasites of the malarial diseases of man have been completely traced. The parasites run through a double cycle, one in man and the other in the mosquito. In our diagram the cycles of only one species are represented; there are however two other special malarial parasites in man.

On either side the head of the mosquito involved is diagrammatically shown, just below the 'cycle in man'.

In man the parasites conveyed by the bite of the mosquito (32) or formed by a division of a parasite already in the blood (7) make their way into the red blood corpuscles (1 and 2), develop there (3 and 4). Some of them ultimately divide to go through the same cycle (5, 6, 7 and back to 1, 2). The process of division corresponds to the period of fever. Others develop into crescent-shaped bodies (8, 9 and 10), which can be differentiated into two slightly different forms corresponding to two sexes (9 male, 10 female). These, if sucked up by a biting mosquito of the right species, pass into the animal's stomach where they develop further (11, 12, 13 male; 14, 15, 16 female) and end by dividing into forms which conjugate (17). The resultant of this conjugation or union of the two sexes (17) develops into a lanceolate form (18, 19, 20) which passes into the cells of the mosquito's stomach (21, 22) and finally penetrates these cells (23). The parasite then secretes a cell-wall and forms a 'cyst' (24), which enlarges (25). The enlargement continues while the nucleus breaks up (26, 27, 28). In the cyst, which is still growing, a large number of needle-like forms develop, each of which contains a fragment of the nucleus (29). Finally the cyst bursts (30), the needle-like forms are cast forth into the body of the mosquito, and ultimately lodge in her salivary glands (31). When the mosquito bites another man, she injects some of her saliva into him through her proboscis. Thus she infects his blood with some of the needle-shaped parasites that lurk in her salivary gland (32). So the cycle is re-enacted again and again. We may note that to prevent this process of repeated reinfection it is only necessary to break either cycle at one point. Thus destruction of mosquitoes or of their breeding-places will suffice, or, again, protection of human hosts from bites of mosquitoes will be sufficient. Either process, if persisted in, will lead to the extinction of the parasite in the region under supervision. In England both methods have been in operation and the disease is almost extinct there so long as any of the malarial mosquitoes remain in one district. However, the disease can always be reintroduced by the introduction of subjects of malaria from without.

(From C. M. Wenyon's *Protozoology*, Vol. II, by kind permission of Messrs. Baillière, Tindall and Cox. Slightly reduced in size.)

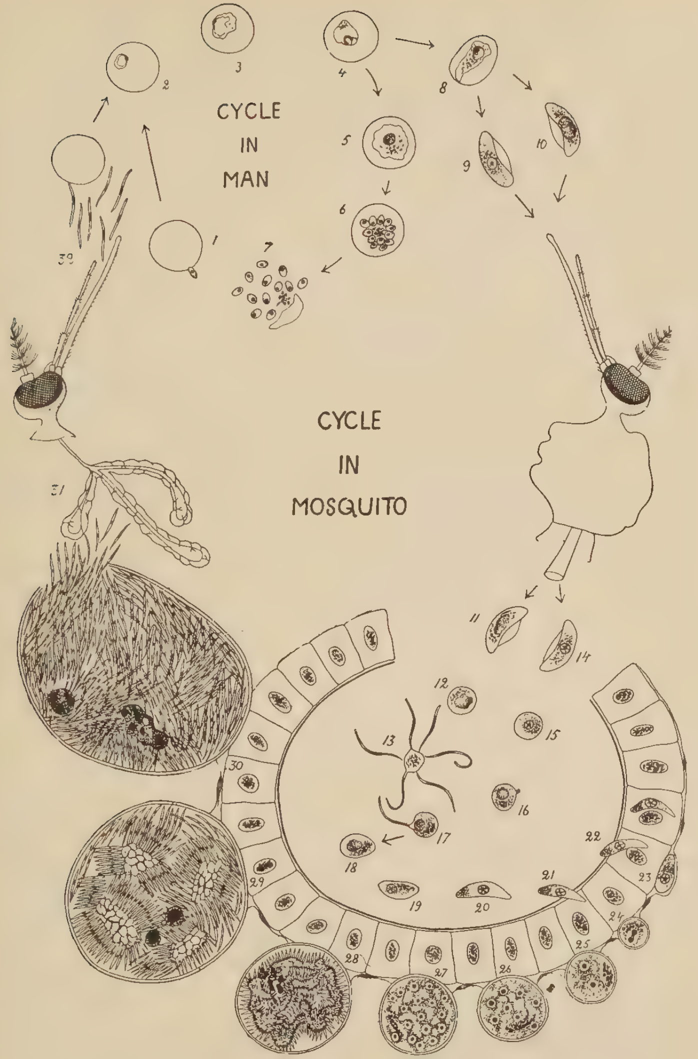


FIG. 123. THE LIFE-HISTORY OF THE PARASITE OF MALARIA

See note opposite.

Malaria has been directed to the mosquito (Fig. 124). Controlling the breeding of the mosquito has proved the best method of reducing the incidence of the disease. Engineering and sanitary works in some places previously infested with Malaria have had the effect of almost entirely eliminating disease. The classical instance is the Panama zone, where, as is well known, the two mosquito-born diseases, Yellow Fever and Malaria, have disappeared. There are now many areas in the Tropics, previously infested, in which the disease is almost unknown. There are many devices for dealing with the mosquito larvae.

By advances such as have been made in the knowledge of Yellow Fever and Malaria, those areas of the Tropics which are under proper sanitary control have become far safer habitats. There is good hope of an early and rapid extension of the process, ultimately rendering new areas of the Tropics suitable for permanent habitation by the white races and healthier and happier places for the coloured.

§ 15. *The Changed View of Insanity.*

Insanity is as old as History. The Bible, Homer, and the *Hippocratic Collection*, for instance, recount numerous examples of the disease. Until the nineteenth century there was practically no scientific knowledge of the conditions classed as insanity. Nevertheless, hospitals for the insane were instituted at an early date. A well-known instance is Bethlem Hospital or *Bedlam* in London, which was developed as an insane asylum in the fourteenth century.

The new era in the treatment of insanity begins with

124 125

FIGS. 124 and 125. A common Malaria-carrying mosquito and a common gnat sometimes confused with the Malaria-carrying mosquitoes. They are both in sitting posture and may be easily distinguished by the attitude that they then assume.

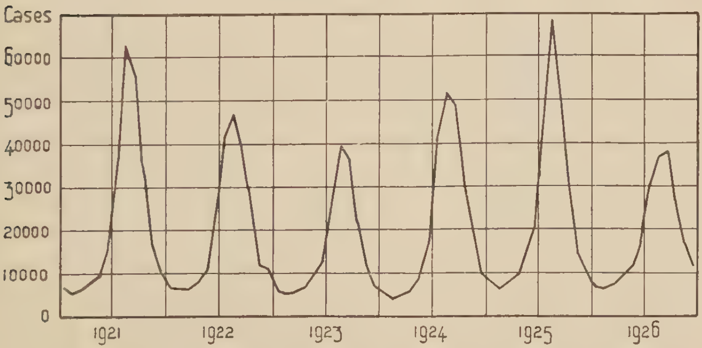


FIG. 126. CHART OF CASES OF MALARIA reported in Italy in recent years, showing the seasonal variation of the disease. The date of the year is written, in each case, below a vertical line corresponding to midsummer. It will be seen that the maximum incidence is always in the months July to September, and the minimum incidence is always in the months January to March. This incidence corresponds to the known facts of the life-history of the mosquito and of the evolution of the malarial parasite within the body of the mosquito.

the abolition of the old system of restraint. This was primarily due to two noble-minded men, one a Frenchman and the other an Englishman. Philippe Pinel (1745–1826), physician at the Bicêtre and afterwards at the Salpêtrière at Paris, at great personal risk both to his life and liberty, insisted on freeing from their chains the unfortunate lunatics under his charge. His *Medico-philosophical Treatise on Mental Alienation* (1791) was devoted to championing the humaner treatment of the insane. His contemporary, the Quaker philanthropist William Tuke (1732–1822), succeeded in 1792 in establishing at York a small retreat for the insane, where the antiquated, unnecessary and cruel restraints were abolished (Fig. 127).

While Pinel was beginning the humaner treatment of insanity in France, considerable interest was aroused in the subject in Germany. There, however, the medical profession was still under the influence of the mystical Stahl (pp. 132–3), who regarded all forms of insanity as perversions of the moral tendencies of the soul, produced by sin!

In France Pinel was succeeded in 1810 by Jean Étienne Dominique Esquirol (1772–1840). The influence of Esquirol was as radical for the scientific study of the subject as had been that of Pinel for the humane treatment of the sufferers. Esquirol threw himself into the task of founding properly conducted asylums, and he produced in 1838 his monumental work *On Mental Diseases considered in their Medical, Hygienic, and Legal relations*. It is the first important, rational, scientific treatise on the subject. Esquirol abandoned the barren type of speculation that had characterized previous

Fig. 127. 'THE RETREAT' NEAR YORK FOUNDED IN 1792
being the first institution in England where the insane were accorded humane and scientific treatment.

works on the subject and devoted himself to the systematic collection of data. He was able to sketch out some of the main forms of insanity, including that now known as 'General Paralysis of the Insane'. This disease was finally differentiated by one of his pupils. Another pupil of Esquirol was the first to succeed in the training of idiots. The main school of French alienists is descended from Esquirol. In the early forties his work resulted in the foundation of journals and societies devoted to the study of Insanity in France, England, the United States, and Germany.

England was behind France in her treatment of the Insane. Not until 1828 were there proper laws governing their certification. In 1844 the great and good Lord Shaftesbury (1801–85), the seventh Earl, brought in his Bill establishing the Board of Lunacy Commissioners with the duty of inspecting all lunatic asylums. It was a subject to which that great philanthropist gave much thought. The same period saw also an awakening in the United States, where Miss Dorothea Lynde Dix (1802–87) carried on a very successful campaign for the better treatment of the insane and the establishment of proper houses for their reception. Her labours resulted in the foundation of many asylums on a reformed model in the United States and Canada. In 1845 the provision of asylums out of the local rates was made compulsory on the local Justices in England.

The late sixties and early seventies saw in every country a further change for the better in the treatment of the Insane. The causes of this improvement were two. On the one hand, Insanity came generally to be recognized as a group of diseases which, like other

diseases, have usually a traceable physical basis. On the other hand, the great improvement of the system of nursing under the inspiration of Florence Nightingale (pp. 298–300) began to reach the asylums. In 1877 there was a Parliamentary investigation into the care of the Insane in England and Wales, and in 1890 the duties of asylum administration were transferred from the Justices to the County Councils. This has resulted in an immense improvement in the accommodation and treatment of the insane poor in England. At the same time the order of a magistrate became necessary for the consignment of a private patient to an asylum. In 1913 provision was made for the mentally defective, who do not come within the Lunacy Act. Lastly, with the establishment of a Ministry of Health in 1917, the general control of the Insane has passed to that body.

Many types of insanity have been traced to an organic cause in the Nervous System itself. The Morbid Anatomy, both coarse and microscopic, of some of these diseases has become recognized. Chief among them is the well-known condition known as 'General Paralysis of the Insane'. During the intensive study of the factors in the causation of Insanity it has become clear that in some groups, as in General Paralysis, which is always preceded by Syphilis, a 'toxic cause' is at work. Other types of toxic insanity are due to the actual intake of a poisonous substance. This is sufficiently evident in cases which are associated with Alcoholism. There is also evidence that in a considerable number of cases toxic conditions result from perversion of metabolic processes, or, again, are associated with 'deficiency' states (pp. 302–8). This is a very hopeful finding, since

by removing the toxic cause, or by remedying the deficiency, relief may be possible.

Much less hopeful is the outlook with those forms of insanity, especially common in the adolescent, which are of the nature of a perversion of development. Such is the large group known as 'Dementia praecox'. These cases almost invariably originate from a mentally unsatisfactory stock. This is less so with the Epileptic insane, though a considerable proportion of epileptics may be classed with those who are born mentally defective and are liable to give rise to a bad stock. Whatever view may be taken of the question of the artificial limitation of human fertility, it is almost impossible to imagine that the free breeding of these classes of defectives, epileptics and their congeners, will continue unchecked in any civilized community.

The general care and treatment of the insane has improved out of all knowledge during the last quarter of a century. It is probable that there is now no class of sick person who is more skilfully and considerately cared for.

From time to time an alarm is raised at the rapid increase in Insanity, and it is a fact that the proportion of certified insane has been, for some time, steadily rising. A considerable part of this rise is certainly due to the greater willingness of the insane themselves to enter an asylum, and of their friends to allow them to do so. Part of the rise in numbers of the insane is due to their increased length of life under improved treatment. It must be remembered that more than 90 per cent. of the insane in England and a similar percentage in other countries are paupers, who are not

readily discharged as they have no means of support. Mild mental cases and the senile insane go now to the improved asylums. Before they would have been kept at home or sent to a rate-supported or a State infirmary. The general conclusion of those best qualified to judge is that Insanity, if increasing at all, is doing so only very slowly.

§ 16. *The New Movement in Psychology.*

During the last half-century various new points of view have entered into our conception of Mind and its disorders. The evolutionary view of the origin of man, which was brought to wide notice by Charles Darwin, not only in his *Origin of Species* of 1859 but also in his *Descent of Man* of 1871 and his *Expression of the Emotions* of 1872, has given rise to new ideas as to the nature of many instincts and emotions. These views have been co-ordinated with our knowledge of lower types of man, both in his existing state and in his extinct and fossil forms. Much that we call Insanity has been found to be related to what is normal in other and less developed environments. The Mind, breaking free from its habitual restraints, 'reverts to a lower type'. There is a constant though unconscious 'conflict' in the mind, which is variously resolved.

Whole schools of Psychology have arisen in the discussion of the nature and resolution of these conflicts. Sigmund Freud of Vienna (1856–) takes the leading place among those who have dealt with this subject. He holds these conflicts to be rooted in sex and has introduced the method of *Psycho-analysis*, which lays great stress on the subconscious or unconscious element in mental life. Largely under the direction of C. G.

Jung of Zürich (1875–), preventive and curative measures, based on this view, have been introduced into medicine. It has been established that painful experiences, lurking in the unconscious mind, disturb the equilibrium of health. Such disturbance is often of the nature of a struggle to repress into the unconscious unpleasant memories which are tending to surge up into the conscious. The psycho-analyst seeks to release the repressed experience into the conscious. The recognition and consideration that follow a success in this attempt is often far less painful than the repression. Persistent unreasonable fears on the part of adults, but especially of children, are frequently thus dispersed.

The importance of suitable environment to children has always been recognized. But a new significance has been given to the mental impressions received in infancy by cumulative evidence of harmful results in the adult life of events in the early years of life that are seemingly forgotten. This recognition of the enduring character of mental impressions has led to a movement for the better instruction of mothers, and has thus been a factor in the remarkable development, in recent years, of work for infant welfare.

It is recognized, moreover, that certain instincts—such, for example, as the self-regarding instinct and the sex instinct—must have expression. Mere repression of such instincts is always harmful, but they are susceptible of a process of transformation, technically known as *sublimation*, to an almost indefinite extent. Thus the self-regarding impulse need by no means lead to the inconvenience and discomfort of others, but, rightly guided, may develop into a sense of personal re-

sponsibility for the welfare of others. So, too, sex instinct is but one aspect of that creative vital activity on which depends the continuance not merely of the human race but also of the culture that the race has built up. The sex instinct is thus habitually sublimed into other creative channels, and there are many altars, beside those of Venus, at which young men and women may kindle their essential fires.

§ 17. *The Revolution in Nursing.*

During the Middle Ages, and in Catholic countries after the Reformation, attendance on the sick in Hospitals and elsewhere was the task of religious sisterhoods. In Protestant countries the absence of these sisterhoods necessitated the employment of women specially for the purpose. The task was not an attractive one, nor did any social distinction attach to it. The profession of nurse became despised and was followed, for the most part, by a low and illiterate type of woman, though midwives were sometimes better educated and of a higher class (p. 180). The great philanthropists of the eighteenth century (pp. 171–72) could do little to improve the nursing profession. The conditions of employment formed the root of the evil. The vast improvement that has resulted in health and happiness to our whole population from the improvement in the character and training of nurses is probably seldom realized, even by medical men. Yet it may reasonably be doubted whether all modern medical and surgical advances put together—apart from Preventive Medicine and Infant Hygiene—have saved as many lives as the Reform of Nursing.

The reader may gain some insight into the life of a nurse from the conditions that prevailed until beyond the middle of the nineteenth century at a very good and well-managed English provincial hospital, the Radcliffe Infirmary at Oxford. The salary of a nurse was £5 a year. There was no distinction between a nurse and a domestic servant. One nurse only was the allowance for a ward of seventeen patients. A nurse's day began at 6 a.m. The wards were cleaned till 7, when a bell was rung and each nurse had to bring down her ashes and sift them under the direction of the porter, who then gave her coals for the day. She took breakfast with the patients, who helped her, so far as they were able, with the ward work. At 2 p.m. she went to the servants' hall, where she had her dinner in company with the servants on daily hire. During the dinner the ward was left in charge of a patient. After dinner she took away a plate of meat and vegetables for her supper. For the night there was normally only one nurse for the whole hospital of about 100 beds. There were no regular holidays, and the nurse was never allowed to leave the hospital before 6 p.m. The practice of nurses receiving gratuities from patients continued till 1870 and even beyond. Those patients who wished to secure a nurse's early attention for their dressings gave tips, those who did not frequently had to wait.

What sort of woman could such a system produce? That some nurses at least were kind and skilful, even under such conditions, is a fact, and is pleasing evidence of the natural goodness and wisdom that reside in the human heart. Many, however, can have been no better than Sairey Gamp and Betsy Prig.

The first important reform in Protestant countries began in Germany, through the influence of Elizabeth Fry (p. 171). In 1822 Theodor Fliedner (1800–64), the young pastor of the church at Kaiserswerth, a little town on the Rhine near Düsseldorf, visited England and was much impressed by Elizabeth's teaching and example. Returning to his charge, he devoted himself to the spiritual and physical care of gaol-birds. In 1833 he and his devoted wife Frederica (1800–42) opened a refuge for discharged female convicts. From them the couple turned their attention to the sick poor. The conception of an organized body of specially trained women crossed their minds. In 1836 they opened a small hospital.

At this hospital six young women of the most spotless character were induced to serve as 'deaconesses'. It was their duty to perform all the tasks of the hospital in rotation. The physicians who attended the hospital gave them instruction. The Kaiserswerth idea rapidly spread and the 'Kaiserswerth Deaconesses' became and remain an important order, which is still occupied in good works in many parts of the world. The conception of the order is different from that of most religious orders in that the members make no attempt to withdraw from the world, and marriage is not forbidden to them. Moreover, the duties of the Kaiserswerth deaconesses are rather different from and more varied than those of a sick-nurse. They include teaching, both secular and religious, nursing, household duties, management of children and convalescents. In 1865 a preparatory school for probationers was opened.

In England Anglican orders of a somewhat similar

character were formed in the forties and fifties. In 1850 and 1851 Florence Nightingale (1820–1910), who was a lady of good social rank, visited Kaiserswerth, and went through a regular training there. She was profoundly impressed by the extremely high character of the deaconesses, most of whom were only peasant women. The next three years she spent in writing and in examining hospitals in her own country.

Florence Nightingale's opportunity came with the outbreak of the Crimean War in 1854, and the rapid breakdown of the medical services, which contained no women nurses. The French had a number of 'religieuses' to nurse their sick, and a feeling of shame arose in England at the neglect and mismanagement of the British sick and wounded. The Secretary of State for War asked Florence Nightingale to go to the Crimea to organize a nursing service. She left at once with thirty-eight nurses whom she selected personally. Ten of these were Roman Catholic sisters and all the others had had nursing experience. From that event dates the Revolution in Nursing. Florence Nightingale performed marvels under conditions of great difficulty (Fig. 128) and in the face of determined opposition. She returned home in 1856 a national heroine. She had no difficulty in establishing a school and home for nurses at St. Thomas's Hospital in London in 1860. The example was followed by the other London hospitals.

Florence Nightingale was a woman of the most powerful will and an admirable organizer and administrator. Her system of nursing contained many new features, not quite all of which have stood the test of time. That nursing rapidly and steadily improved

Fig. [illegible] FLORENCE NIGHTINGALE RECEIVING WOUNDED AT SCUTARI

From a painting by Jerry Barrett

from the moment she was in authority cannot at all be doubted. Looking back, it is apparent that the immediate success of her methods was due to two main factors. First was her capacity to secure women of high character and good social position to accept positions of responsibility. Second was her removal of the control of the nursing staff entirely from the hands of men into those of women. Her influence soon passed across the Atlantic, and she was associated with the United States Sanitary Commission and the women who took charge of army nursing during the American Civil War.

While Florence Nightingale was reforming Nursing, her contemporary, Mary Carpenter (1807–77), was applying herself to the kindred task of looking after neglected children, establishing Reformatory and Industrial Schools and improving the position of Indian women. She obtained a large measure of public support and exercised considerable influence in America, which she visited in 1873. Many other distinguished and devoted women worked on similar lines.

Among the indirect results of the activity of Florence Nightingale was the establishment at Geneva in 1864 of the International Red Cross Committee, the branches of which have done good service in many wars and have been no less useful in peace.

Florence Nightingale opposed anything in the way of State registration of nurses. Concentrating on a high ideal of competence and character for the nurse, she failed to grasp some of the secondary effects of her own scheme. A large nursing service is now a necessity in every civilized country, as a result of her efforts and example. Having regard to human imperfections, we

can as little hope that every woman who nurses will be a born nurse, devoted to her task, as that every doctor or teacher will have a natural vocation for his work. In an imperfect world mankind must protect itself against the incompetent and the unfit. Registration is a way—doubtless an imperfect way—of doing this. A Nurses' Registration Act became law in England in 1919.

There have been many improvements in the details of the training of nurses, incident on the changes in Medicine and Surgery during the last half-century. Apart from these, the main improvements in Nursing have been due firstly to an increased interest in the welfare and health of the nurse herself, and secondly to the recognition that Nursing is a profession for which, as for Medicine, some preliminary scientific knowledge should precede professional training. Thus, the very long hours of the nurse have of late been reduced, and in the best schools instruction is now given to nurses in Anatomy, Physiology, Hygiene, Bandaging, and Cookery, before the commencement of actual hospital work.

Further developments will probably be along the lines of State and Municipal Nursing Services. Since Health is a public as well as a private concern, the same must be true of the training and work of nurses.

§ 18. *Some Modern Physiological Concepts of Clinical Import.*

The vast activity in the sciences of Physiology and Pathology during the last fifty years, and their repeated divisions into independent sciences, each prosecuted by its own specialists, have yielded many ideas which

have been imported into the clinical practice of Medicine. It is impossible to say which of these are of permanent value. All previous ages have had to discard part of the practice and a large proportion of the medical ideas that have been handed down to them, and there is no reason to suppose that the age that follows us will differ from those which have gone before us. Some ideas that have entered Medicine from the physiological laboratory, pushed by interested parties or seized on in despair by physicians at a loss for a line of treatment, are already seen by men of experience and judgement to be no permanent addition to our store. Other lines of physiological thought are still under discussion by them.

There are, however, certain physiological conceptions which, apart from their general implications in the economy of the body, have received such wide application that their future, as an organic part of medical practice, seems assured. Certain of these conceptions demand discussion in even the most cursory survey of medical development.

(a) *Ductless Glands and Internal Secretions.*

The nature and action of the various glands of the body has been a classical physiological field. Malpighi (pp. 116–20) was the first to investigate the structure of these organs, and he was followed by many others. It became evident that many glands, such as the liver, the salivary glands, and the tear glands, are provided with ducts or tubes, which carry off the characteristic secretion of the glands. These secretions can be examined with comparative ease—as happened early with the

secretion from the stomach, or 'gastric juice' (pp. 146–48), and later with the secretion of other glands. There remain, however, certain glands unprovided with ducts. The action of such 'ductless glands' long remained a mystery. Of these the type is the 'Thyroid gland'. Much of our physiological knowledge of this organ, together with the conception of its function as indispensable to normal life, has come through Surgery.

It had long been known that certain symptoms were associated with enlarged Thyroid gland or 'Goitre'. Attempts to remove the organ surgically were made after the introduction of antiseptic methods. Goitre is particularly common in Switzerland, and it is not remarkable that the technique of the very dangerous operation for the surgical removal of goitres was first perfected by Swiss surgeons, among whom Theodor Kocher (1841–1917) has taken the first place. The study of cases that had had their Thyroid glands removed gave a clue to the nature and action of the gland.

It was found that those surgically deprived of the Thyroid gland develop abnormal slowness in movement and response. The temperature is low, the pulse small, the muscles are torpid and sometimes rigid, and there is a failure in ordinary fine muscular movements. The patient shows a thickening and swelling of the skin and presents a dull and very characteristic appearance. When the operation was performed on one whose growth was not yet complete, development was checked. Such a patient remains infantile or childish both in body and mind.

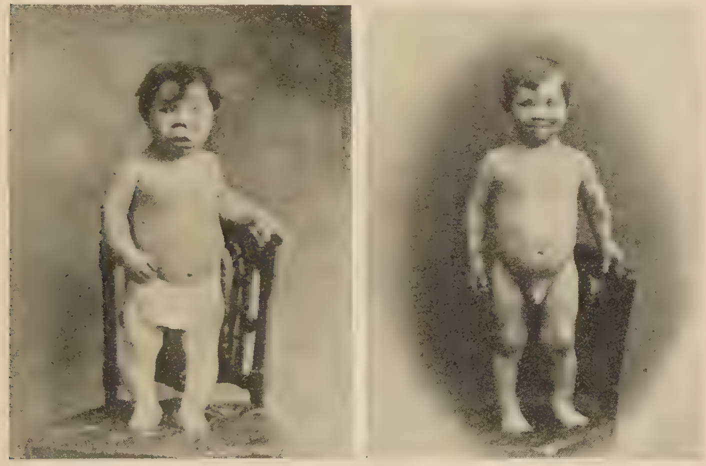
The conditions were recognized by Swiss surgeons in the seventies as resembling those of a spontaneous

disease to which the name *Myxoedema* was attached. Further the close relationship both of the surgical and of the spontaneous condition to the state of idiocy known as *Cretinism* came gradually into view. In Switzerland, as in other parts of Europe, stunted beings known as *Cretins* had long been known. These defectives are sometimes goitrous, sometimes without a Thyroid gland, but their general appearance and condition is an exaggerated version of what has been described for those with Thyroid glands removed (Fig. 129).

The result of these observations was to direct the attention of physiologists to the Thyroid gland. It was soon found that the symptoms of Thyroid deprivation could be experimentally produced in animals. Moreover, it was shown by Moritz Schiff of Berne (1823–1890), in 1884, that the results of the removal of the Thyroid might be avoided if the animal were fed regularly on an extract of the glands. The results were soon applied to man and have led to one of the greatest of medical triumphs. By its means sufferers from myxoedema and cretinism can be either cured or improved. A drivelling and idiotic cretinous child, adequately treated with Thyroid, enters on a normal process of development. The improvement is almost incredible, and the child rapidly passes into a healthy and happy state, so that it is literally true to say that his own parents would not recognize him (Fig. 130). Further, the gland may be given in excessive doses, and a condition produced that closely resembles a well-known pathological condition known as 'Exophthalmic Goitre', which is similarly susceptible of experimental investigation.

The facts here enumerated justify the deduction that

the Thyroid gland secretes something which is essential to normal well-being. The organ has no duct, and the secretion is, therefore, never normally thrown out of the body. The Thryoid is, in fact, an organ of what is called 'internal secretion'. Investigations on this secretion led to the isolation of the active principle as a pure



FIGS. 129 and 130. CRETINOUS INFANT BEFORE AND AFTER THYROID TREATMENT.

From the Collection of the Royal College of Surgeons.

compound known as *Thyroxin* in 1916. The story of the Thyroid has recently (1926) been rounded off by the preparation of Thyroxin synthetically. The synthetic product has been given with effect in cases of Myxoedema.

The observations made on the Thyroid directed further attention to other ductless organs of which a number have been shown to have their own 'internal

secretions'. Furthermore, it has been demonstrated that, among organs which throw out their products through a duct, there are those which also send an internal secretion into the blood-stream. Among these are the essential organs of sex, the testicle and ovary. The effect of castration on the general physique is well known. It may be compared with the effect of 'spaying' or the removal of the ovary. This operation leads to an assumption by the female, in more or less modified degree, of the secondary sexual characters of the male.

Peculiarly interesting for their practical results have been certain investigations made of late years upon the organ known as the 'Pancreas'. The Pancreas has a duct which opens into the Intestine just below the Stomach. It has long been known that the secretion of the Pancreas is related to the amount and fate of sugar in the blood. The association of disease of the Pancreas with the symptom known as 'Diabetes', in which sugar appears in the urine, was also familiar. Later it became apparent that it was not the Pancreas as a whole that was related to the process but only certain isolated and peculiarly formed nests of cells. It is now possible to administer extracts of these cell-nests with very favourable results on the course of certain types of Diabetes. The extract is now in wide use under the name of *Insulin*.

Among the ductless glands that have been best investigated are the so-called 'suprarenal bodies', which lie above the kidneys. As with the thyroid gland, the attention of physiologists was directed to these bodies as a result of clinical observations. These observations date back to the middle of the nineteenth century. In the last years of that century it was observed that an

extract of the suprarenal bodies, injected into the circulation, caused a rise in blood-pressure, an effect opposite to that following the extirpation of the glands. The administration of extract from suprarenal bodies has found wide clinical application. Unlike the extract of thyroid, the effect of this extract is very temporary. It is easily oxidized and rapidly disappears from the blood. It belongs to the group of substances which are known as *hormones*. The active element in a suprarenal extract, the 'suprarenal hormone', has been recently prepared by a synthetic process.

The nature of hormones has only come clearly into view of late years. The word 'hormone' is formed from a Greek word meaning 'to excite'. The internal secretions have, in general, functions of considerable physiological complexity, and act, for the most part, slowly and continuously. The hormones are, however, exceptions to this rule. They act rapidly and in an excitatory manner. These substances appear to be of relatively simple chemical structure. They are easily oxidizable, so that they rapidly disappear from the body. They act, in fact, as 'chemical messengers', producing a state of 'chemical correlation' of the different parts of the body which is comparable to the better-known and more widely recognized 'nervous correlation'.

The hormones represent a very ancient and primitive physiological mechanism. In organisms consisting of but one cell, in which there are very few differentiated organs, the messages from one part of the body to another are necessarily of a chemical or hormonic character. In higher multicellular animals the intercommunication between different parts of the body is

maintained, for the most part, by a specially developed nervous system. Certain necessary messages are, however, still conveyed by chemical messengers. The development of the conception of hormones has been especially the work of the London physiologist E. H. Starling (1866–1927).

Internal secretions and especially hormones form part of the increasingly complex picture of the working of the animal body. They are not only of great physiological value, but have also entered the department of practical therapeutics. They are, moreover, of philosophical importance, since they yield us a conception of the body in which every part is dependent on every other part, and the whole is subject to a process of 'integration' or linkage into a unitary system. We have glanced at the mechanism of chemical integration. We have now to turn to the mechanism of nervous integration.

(b) *Nervous Integration.*

If the simple reactions of animal bodies are tested, it will be found that they clearly serve certain ends. Lightly touch the foot of a sleeping child and it will withdraw it. Tickle the ear of a cat and it will shake it. Exhibit savoury food to a hungry man and at once his digestive process will get to work—his mouth will 'water'. These instances might be multiplied a hundredfold. Such reflexes are admirably adapted to their ends. Many of them will continue in an animal in which the spinal cord is severed from the brain. Nevertheless, in the higher animals, and especially in man, they are controllable to a greater or less extent by the will. But to leave the question at that would give a

false idea of the extremely complex integrative functions performed by the nervous system. Thus, the spinal cord, which, to the naked eye, is a longitudinal and little differentiated nervous mass, is, in fact, a collection of nerve-centres which have historically, both in the individual and in the race, been formed by the union of a series of separate segments. Each one of these segments is dependent on the action of the next segment in a fashion somewhat similar to that in which the actions of the cord itself are dependent on the brain. Each of the sections governs certain functions or movements of the body. There is thus a very complex process of integration which runs right through the nervous system.

The investigation of the bodily functions of a chemical and physical nature reveals that these activities are far more largely under nervous control and discipline than was at one time conceived to be possible. Thus, the main factor in the activity of any part is its blood-supply, but the blood-supply is largely determined by the state of contraction of the vessels of supply, which are in their turn under nervous control. So it is with the state of nutrition of the muscles, with the action of the sweat glands of the skin, with the mechanism of childbirth, and with a thousand bodily states with which both physician and biologist are concerned.

The investigation of nervous integration is especially associated with the name of Sir Charles Sherrington of Oxford. As the outcome of his work the picture formed of the nervous apparatus is that of a machine in which some parts work spontaneously, automatically, and with complete uniformity; others, though mainly

automatic, are susceptible of various degrees of alteration and adjustment; others need intermittent or constant attention, and demand for their functioning fresh supplies of energy at longer or shorter intervals; while, finally, others have hardly yet taken a fixed form and are improvised as occasion demands. Thus the nervous system is a system of systems of every degree of independence.

These systems, each with a certain individuality of its own, date from every stage of Evolution, the more ancient being, as a rule, the more automatic and the less dependent on other systems. The most ancient, the chemical messenger or 'hormonic' system (pp. 306–8), we share with the lowest living things which consist of only one cell. Very recent are the factors in the nervous system that are specially developed in man as contrasted with the higher apes. Such are those associated with the delicate co-ordination of sensory impressions and motor impulses involved in such acts as speaking, reading, writing and the like. Each of these systems, high or low, ancient or recent, has its own place in the body. For many the exact position of the controlling centre is demonstrable and some of the lower systems can function without the aid of any other systems save those which control their nutrition.

Among these nervous relations there is one which calls for special mention on account of its great clinical importance. The state of 'shock', the general nature of which is vaguely understood by everybody, has been given a more exact physiological meaning of late years, especially by the American surgeon G. W. Crile (1864–). It has been found possible to localize 'shock'

experimentally. If a section of the spinal cord of an animal be cooled to a point just above freezing, the part of the body below the cooled level passes into a state of 'shock', that is to say, its reflexes no longer respond to irritation in the normal fashion. This shock effect is due to the removal of some influence exercised by the higher parts of the nervous system. In the experiment the shock effect is induced by an external agent, but there is an internal mechanism within the nervous system itself, which can cause it under appropriate conditions.

(c) *Vitamins.*

There are no current medical problems that are more discussed than those of nutrition. It has long been recognized that articles of diet may be classified according to their constitution into 'proteins', 'carbohydrates', and 'fats'. If an animal is fed on a diet containing these in correct proportion, but in a perfectly pure state, it will become ill and ultimately die. The onset of illness and death will be the more rapid if it be a young animal. This fact, observed as long ago as 1880, was reinvestigated by F. Gowland Hopkins of Cambridge in 1906, from whence dates our real knowledge of a very important subject. He found that, in the case of rats, the addition of a very small quantity of milk to this chemically pure diet would induce normal growth. The milk must therefore contain some growth-promoting substance or substances other than protein, fat, or carbohydrate. The result of many similar experiments by a large number of observers has shown that almost all fresh food contains such growth-promoting substances. They have been named 'vitamins'.

Several of these vitamins have been distinguished. None, however, has been isolated, and we depend for our knowledge of them on our investigation of their mode of action. One, known as *Vitamin A*, is produced in the growing green parts of plants, and is especially necessary for the promotion of growth. Vitamin A is abundant in cod-liver oil. It has been shown that the necessity for Vitamin A can to some extent be evaded if the animal is exposed to sunlight or ultra-violet rays. Moreover, it has been shown that the absence of Vitamin A or of some allied substance is associated with the disease of the bones known as 'Rickets' or 'Rachitis'. The history of this disease (p. 181) is made intelligible by our knowledge of these facts. Rickets can be shown to be most prevalent under precisely those social conditions in which articles of diet containing Vitamin A are scarce and the amount of sunlight is inadequate.

Our knowledge of this topic is in the process of active extension. The question of the actual influence of sunlight and of the rays of various wave-length which go to make it up is still too uncertain for discussion here. There is a special aspect of this topic, however, to which we may refer. It has been demonstrated that stable-fed cows, fed not on fresh food but on oil-cake, yield milk of little antirachitic power. It has, however, been shown that this milk becomes antirachitic after exposure to ultra-violet light. Therefore, some antirachitic substance is produced in the milk, as in the body, by the action of ultra-violet light. Now recent research has shown that the antirachitic elements are associated with a chemical substance known as *Cholestrol* which is of the nature of a complex alcohol. Nevertheless

chemically pure Cholestrol has no antirachitic power, though it, too, acquires it by exposure to ultra-violet light. By chemical means 99·9 per cent. of rayed and antirachitic Cholestrol has been recovered as pure Cholestrol without antirachitic power. Therefore the antirachitic power, that is the vitamin factor, resides in the remaining one-tenth per cent. of rayed Cholestrol. The further investigation of this fraction may be expected to yield results of great importance both theoretically and practically.

Another substance of the same order exists in the husks of rice. If animals such as fowls be fed on a diet of rice deprived of its husks, they develop a nervous affection. Now a somewhat similar nervous affection known as 'Beri-beri' is known in the East among natives who live on milled rice. The disease, whether in human beings or chickens, may be cured or avoided by giving the husks of the rice separately. The substance thus conveyed has been named *Vitamin B*. There is yet another disease, Scurvy (p. 170), which occurs in those who have been deprived of fresh food. *Vitamin C*, which cures this, is specially found in the juices of oranges and lemons. Our knowledge of 'deficiency diseases', of which Scurvy is one, is only just beginning. It may well be that they are of wider occurrence than has been supposed, and vitamins may be important curative and preventive agents.

§ 19. *Knowledge of the Eye and its Disorders.*

From an early date the treatment of ailments of the eye has stood somewhat apart from the rest of medical practice. Moreover, the knowledge of the structure and functions of the parts of the eye has not

kept closely parallel with that of other departments of anatomy and physiology.

The eye is a roughly spherical organ, enclosed in a tough capsule, the *Sclerotic coat* (Fig. 131). The transparent front of this capsule, the *Cornea*, is the curved

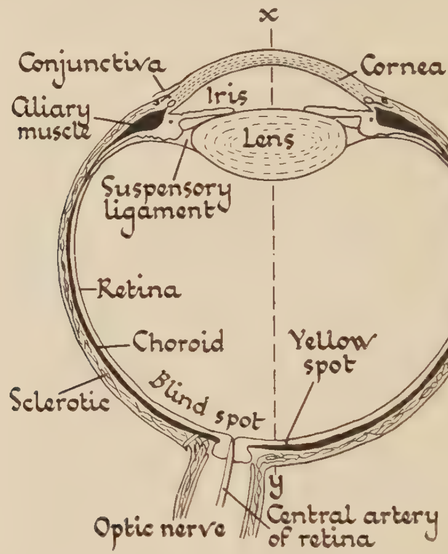


FIG. 131. DIAGRAM TO SHOW THE STRUCTURE OF THE EYE, REPRESENTED IN SECTION. For description see pp. 314–15.

window through which we look upon our world. There is a watery space, the *Anterior Chamber*, behind the Cornea, at the back of which is situated the *Lens*, a horny transparent structure. In front of the Lens is a ring-shaped pigmented muscle which shuts out light from the Lens, except at the centre, and gives the characteristic colour to the eye. This circular coloured muscle is the *Iris*, and the hole in its centre is the *Pupil*. The

pupil becomes smaller or larger with contraction or expansion of the Iris. This change is a reflex and unconscious act, depending on the amount of light and also on the degree to which the eye is adjusted to examine near objects.

The edge of the Lens of the eye is attached by the circular *Suspensory Ligament* to the circular *Ciliary Muscle*. The Ciliary Muscle, by contracting or relaxing, alters the form of the Lens (Fig. 132). This change in form of the Lens is part of the process of adjustment to near or distant vision. Behind the Lens is the large *Posterior Chamber*, containing a transparent gelatinous substance. At the back of the posterior chamber is the sensitive area or *Retina*, which is the essential organ of vision, and is backed by a pigmented coat, the *Choroid*. The Retina is continuous with the *Optic Nerve*, along which an artery enters the globe of the eye. At the point where this artery pierces the Retina there is the so-called *Blind Spot*.

A ray of light penetrating the eye from the centre of the Cornea through the centre of the Lens falls on or near a specially sensitive area, the *Yellow Spot*, and images formed there are more distinctly perceived than those formed elsewhere. When an object is examined closely, the observer makes the attempt to bring the image of it on to his Yellow Spot. Any injury to the Yellow Spot causes a great diminution in clearness of vision. Man and his allies, the zoological group known as the 'Primates', are the only mammals, except the cat tribe, that possess a Yellow Spot. There can be little doubt that the possession of this Yellow Spot has done much to raise the importance of vision among the

senses in the Primates. It has thus been a very potent factor in the evolution and elevation of Man himself.

The eye is an optical instrument which, like other instruments, performs its functions with something less than perfection. Most purely optical errors of the eye can be remedied by spectacles. These aids to vision are of very great importance, since, by the time middle life is reached, few are fortunate enough to read in comfort without them. The introduction of spectacles, therefore, enormously extended the active intellectual life. Their social effects are incalculable.

The commoner optical errors may be classified under four heads.

First and commonest there is 'old sight'. When a healthy eye adjusts to near vision, the Ciliary Muscle contracts towards its attachment at the junction of Conjunctiva and Sclerotic. This draws forward and relaxes the Suspensory Ligament. The elasticity of the Lens, no longer constrained by the Ligament, causes it to assume a more convex form. This more convex form is appropriate to the correct focussing of a near object on the Retina. At or about the age of forty-five the Lens usually begins to lose its elastic power, and thus has difficulty in adapting to near vision. The trouble is remedied by the use of convex glasses for reading or other near work.

A second common error is the so-called 'far sight'. In this form—save in extreme cases—the eye is competent for distant objects, but those that are near are not clearly seen. The incapacity for near vision is due to a deformity—usually innate—of the eye. The eye is too short along the axis *xy* (Fig. 131). The resulting

optical error can be remedied by the use of convex spectacle lenses.

Thirdly, there is the so-called 'near sight'. In this state near objects can be clearly seen, but vision fails with those that are more distant. Near sight is usually an acquired condition. The eye is too long along the

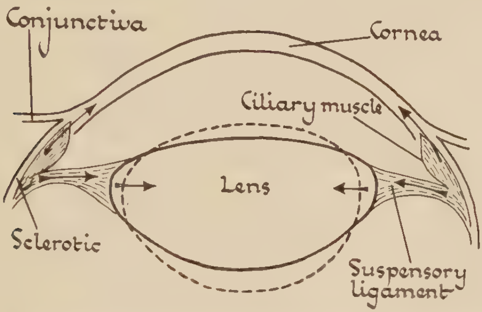


FIG. 132. DIAGRAM TO SHOW THE NATURE OF ACCOMMODATION OF THE EYE TO NEAR VISION. The Ciliary muscle, by contracting, pulls forward the lateral attachment of the Suspensory Ligament to the Sclerotic. Thus the ligament is relaxed and in turn relaxes its pull on the Lens. The Lens thereon becomes more convex. As age advances the Lens loses this power and so the sight fails for near vision.

axis *xy* (Fig. 131). The resulting optical error can be remedied by the use of concave spectacle lenses.

Fourthly, there is 'irregular sight', known as 'astigmatism'. In extreme cases of this condition no perfectly clear image can be formed of any object, whatever its distance. It is in some measure both congenital and acquired, and is due to an irregular deformation of the optical apparatus of the eye. The remedy for astigmatism is a compensatory deformation of the spectacle lens, which may need, in other respects, to accord to the convex or concave form, according as the

deformation of the eye is of the far-sighted or near-sighted type.

Historically optical errors of the eye were relieved by spectacles before the nature of the defects was understood. The first suggestion of the use of convex lenses as an aid to old sight was made by Roger Bacon (1214–94) in the thirteenth century. Spectacles with convex lenses for old or for far sight first came into use about 1300. By the fifteenth century they were widely known. It may well be that their adoption, by prolonging reading life, had an important effect upon that process of extension of knowledge that we dub the 'Revival of Learning'. Concave lenses for the relief of near sight came in towards the end of the fifteenth century, but were not widely used till the eighteenth century. Astigmatic lenses were not contrived till well into the nineteenth century.

In 1874 S. Weir Mitchell (1830–1914), a very able American physician, showed that the eye strain resulting from astigmatism was associated with many nervous conditions. Weir Mitchell's name is familiarly associated with a line of treatment of these conditions. Since his discovery it has been the practice to examine for optical error all sufferers with headache and other neurotic symptoms.

For long there was no means of estimating the degree of error, whether of old sight, far sight, or near sight, save by trial on the part of the patient himself. Spectacles were a common object of the hawker's trays, and from them the sufferer selected the specimen that suited him best. The first essential improvement in this state of affairs was an elucidation of the mode of action of lenses. The paths of light rays in their passage

through a lens were first correctly determined at the beginning of the seventeenth century by the astronomer Johannes Kepler (1571–1630). Knowledge of optics advanced during the seventeenth and eighteenth centuries, but the optical errors of the living eye were not accurately estimated until the time of the great Dutch ophthalmologist Frans Cornelis Donders (1818–89). The system of prescribing and fitting spectacles that is now in vogue dates from the publication of his work, *The Anomalies of Refraction and Accommodation*, in 1864. Hardly less important was the invention of the opthalmoscope by Hermann von Helmholtz (p. 213). Very important also was the introduction of 'test types' for examining errors of vision by the Dutch ophthalmologist Hermann Snellen (1834–1904).

One of the most remarkable minds that has ever applied itself to medical problems was that of the Quaker physician Thomas Young (1773–1829). He was a man of immense learning, and is remembered for having been the first to decipher Egyptian hieroglyphics. Young explained the power of the eye to 'accommodate' for near vision. This faculty of 'accommodation' was, he showed, due to changes in the curvature of the crystalline lens (Fig. 132). In his memoir *On the Mechanism of the Eye* (1801), Young gave the first scientific account of Astigmatism. His theory of colour vision and his doctrine that light is due to waves in the ether are still important. His 'wave theory' of light completely replaced the old view, the so-called 'emission theory', that light is due to something material which goes forth from the luminous object. While we are referring to Young we may re-

mind the reader that his work on 'Energy' lies at the back of all modern Physics, in the history of which he takes an extremely important place.

The operative treatment of the eye is of great antiquity. The most important operative procedure is that for 'cataract', a condition caused by an opacity of the lens. 'Couching' for cataract, that is depressing the opaque lens, was practised by Alexandrian surgeons in the third century B. C. It is described by Celsus (p. 43) in the first and mentioned by Galen (p. 50) in the second Christian century. Contemporary with these authors are descriptions of the actual extraction of the lens affected with cataract.

In Imperial Roman times there were surgeons who devoted themselves exclusively to cataract operations. These were practised during the Middle Ages by the Arabs and to a less extent by the Westerns. For the most part the operations were performed by wandering quacks, who were, however, often very skilful. In the sixteenth century operations on the eye began to pass into the hands of recognized medical practitioners. The advances in the knowledge of the anatomy and physiology of the eye in the eighteenth century enabled the French surgeon Jacques Daviel (1696–1762) to explain the real nature of cataract, which is usually nothing but a senile change in the lens of the eye. His knowledge made it possible for him greatly to improve the operation for extraction, so that, over a large range of cases, he had only 11 per cent. of failures.

The modern era of ophthalmic surgery was ushered in by Donders (p. 319), von Helmholtz (pp. 213 and 319), and Albrecht von Graefe (1828–70). The last was

a professor at Berlin who greatly improved the operation for cataract and introduced or improved many other important operations on the eye. He was one of the first to make important clinical observations with the ophthalmoscope, and he showed how the instrument may be made to yield information not only of the condition of the eye itself, but also of the brain and of its membranes, an application which has become of the greatest value in later medical developments. Though he died before the most important work of Pasteur and Lister had become generally accepted, von Graefe was yet practising a system of surgery which was not far from aseptic.

As with most departments of Medicine, so also with Ophthalmology, the most significant advances during the last generation have been in the direction of prevention rather than cure. Prominent among these measures are, firstly, school inspection with the consequent early detection and isolation of infectious cases of conjunctivitis; secondly, maternity welfare accompanied by prompt notification and treatment of the very dangerous and sight-destroying 'Ophthalmia of the Newborn'; thirdly, improved light regulation in factories and schools; and, fourthly, adequate provision of spectacles for school children with errors of vision.

The recognition of the infectious character of the very chronic and sight-destroying disease known as *Trachoma*, or 'Granular Conjunctivitis', has been of great importance for the Public Health. The disease is common in the near East and in Eastern Europe and by no means rare in slum quarters in the West. A rigid system of inspection of immigrants, together

with quarantine combined with treatment, has done much to diminish its ravages in the United States.

§ 20. *Investigation of the Nature and Action of Drugs.*

(a) *Entry of Vegetable Drugs into the Pharmacopoeia.*

An examination of the list of drugs that are in use at the present day—apart from those which have been introduced by the scientific movement of the last generation—yields some surprising results. Some thirty per cent. of the crude vegetable drugs in the modern official Pharmacopoeia were known in remote antiquity. The Egyptian medical papyri mention, among others, Aloes, Caraway, Castor Oil, Coriander, Dill, Fennel, Juniper, Mint, Myrrh, and Turpentine. Among Egyptian mineral remedies still in use are salts of copper and of lead. Assyrian medical tablets refer to most of the Egyptian drugs as well as to a number of others, among which are Almond Oil, Aniseed, Galbanum, and Liquorice. Among Assyrian mineral remedies that are used by us to this day are Alum and Bitumen. Early Indian medicine had a very copious pharmacopoeia. *Cannabis indica*, known as 'Hashish' or 'Indian hemp', Cardomoms, *Cassia fistula*, *Datura stramonium*, and *Nux vomica* are among the valuable Indian herbs now in use in scientific medicine, while Mercury preparations were perhaps ultimately of Indian origin.

The medical herb lore of the Greeks comes to us chiefly from Dioscorides (p. 43), who mentions about five hundred plants. A large number of these are still in our own Pharmacopoeia. Among these, besides those of Egyptian, Assyrian, and Indian origin, are Ammoniacum, Belladonna, Camomile, Catechu, Cin-

namon, Colchicum, Colocynth, Crocus, Galls, Gentian, Ginger, Hyoscyamus, Lavender, Linseed, Male Fern, Mallow, Marjoram, Mustard, Poppy, Rhubarb, Sesame, Stavesacre, Storax, Terebinth, Tragacanth, and Wormwood. About thirty-seven per cent. of our Pharmacopoeia was known to the later Greeks. From them the Arabs derived, adding, however, enormously to their drug-lists, so that we may say that about fifty per cent. of our drugs were in use by the Arabic-speaking physicians of the Middle Ages. With the discovery of America further important additions were made. Of these we have already discussed the introduction of Cinchona, Ipecacuanha, and Tobacco (p. 95). Few important additions were made in the eighteenth century, though among them was Digitalis (p. 328).

(b) *Active Principles.*

One of the things that separate the practice of Medicine of our time from that of previous ages is our power to give drugs in 'pure' form. This means not only that we can secure drugs without adulteration, but also that the active substances in drugs can be chemically isolated and given without admixture. Most drugs used in Medicine are, in fact, of vegetable origin. The possibility of giving them in chemically pure form depends upon the discovery, early in the nineteenth century, that plants owe their poisonous and remedial properties to small quantities of *Active Principles*, which are susceptible of chemical extraction and isolation. Thus the science that deals with the action and nature of drugs, *Pharmacology*, really took its rise about a hundred years ago, though many had experimented with drugs at an earlier date.

Further progress in the same direction has been made by the so-called 'synthetic' preparation of drugs. Certain substances of vegetable origin do not readily yield their active principles and to extract them very complex chemical processes may be involved. There are special obstacles to the complete purification of other drugs, even when they have been obtained in a relatively pure state. These difficulties can sometimes be surmounted by the preparation of the drug from inorganic materials. This synthetic process of preparation is now possible for many substances that are of medical application. Furthermore, when a drug can be thus synthetically prepared, it is often possible to try chemical variants upon it, and thus to obtain a more effective preparation.

In former times a vast number of drugs were habitually employed by physicians, and they were often given in very complicated prescriptions. 'Polypharmacy', the giving of many drugs, is a vice from which Medicine has now in large part freed itself. The number of drugs given by scientific physicians is far fewer than it was. For this there are several reasons. Firstly, many drugs were found useless for the purpose for which they were administered, and were at times even dangerous. Secondly, since attention has been drawn to the active principles of drugs rather than to the crude natural drugs, it has been seen that, in fact, many of the drugs that were being given were merely duplicates one of another, and that often the administration of the active principle itself was more effective and more reliable than that of the source from which it was obtained.

What then is the nature of the drugs now being

administered by scientific physicians? They fall into a number of classes. The nature and action of some of these is so simple that no prolonged discussion of them is necessary. There are, for instance, the inorganic acids and alkalis, the primary action of which, when taken internally, can be determined by a series of experiments on gastric juice in a test-tube kept at body temperature. Again, there are soluble inorganic salts, which are absorbed unchanged from the alimentary canal. These have the effect of increasing secretions. Their purgative effect is well known, though the physiological details of their action are not yet clear. There are yet other substances, such as metallic Mercury in 'grey powder' or Bismuth, which act mechanically, even when administered internally. Over and above these simpler substances, and in addition to the traditional vegetable substances which have been in use as medicines for centuries, there are others which have only been accessible during the last few generations. We have already discussed under separate headings the derivatives from animal glands, such as of the Thyroid (p. 305), of the Adrenals (p. 307), or of the Pancreas (p. 306), as well as the bacterial Vaccines (p. 261) and Antitoxins (p. 267). We now turn to pure chemical substances of vegetable origin. Of these mention may be made especially of the groups known as the *Alkaloids* and the *Glucosides*.

(c) *The Alkaloids.*

By 'Alkaloid' is understood a nitrogenous substance, usually of vegetable origin, which forms salts with acids. The alkaloids are mainly obtained from the

dicotyledonous plants. Generally they occur in nature in combination with plant acids such as citric or tartaric acid. The alkaloid group contains some of the most important drugs that we possess. Among them are Morphine, Strychnine, Cocaine, Atropine, and Quinine.

The investigation of the alkaloids began with the nineteenth century. Morphine was isolated from Opium by the Parisian apothecary Charles Derosne (1780–1846) in 1803. He failed, however, to recognize its chemical affinities, which were first grasped by the German apothecary Adolf Sertürner (1783–1841). Their work, however, attracted but little notice until attention was drawn to it by the great French chemist Joseph Gay-Lussac (1778–1850), in 1817. The result was the concentration of much scientific ability on the alkaloids. Prominent among the early investigators were the French pharmacologists Pierre Joseph Pelletier (1788–1842) and Joseph Caventou (1795–1878). Between 1818 and 1820 they isolated from Cinchona (p. 95) certain alkaloids allied to Quinine, from Nux vomica the alkaloid Strychnine and certain of its allies, and from Coffee the alkaloid Caffeine. Pelletier in conjunction with the distinguished chemist Jean-Baptiste Dumas (1800–84) followed this by a quantitative examination of a number of alkaloids in 1823. The first alkaloid to be used as such in medicine was Strychnine. It was introduced in 1821 by the French physiologist François Magendie (1783–1855), the teacher of Claude Bernard.

In the thirties and forties of the nineteenth century Liebig, who had developed his doctrine of radicles (p. 206), attempted to determine the formula of alka-

loids. He was followed by Wöhler (p. 206). Since then an immense amount of work has been done in investigating the chemical nature and physiological action of alkaloids. The general result has been to reveal the fact that each alkaloid-yielding plant contains not one but a number of alkaloids. Those from the same plant often have similar but not identical action upon the animal body. The differences in physiological action of allied alkaloids have occupied much of the attention of pharmacologists. The accurate knowledge of these differences has made possible a far greater finesse in the administration of alkaloid drugs than was previously possible. Some alkaloids can be prepared synthetically, but the process is mostly of theoretical rather than practical importance.

(d) *The Glucosides.*

The Glucosides are an ill-defined group which have in common the property of yielding a sugar-like substance—usually glucose itself—as a result of certain chemical processes. They are mostly of vegetable origin and the history of their investigation has been parallel with that of the alkaloids. The first glucoside to be isolated was Salicin, which was obtained from willows in 1819. It is the active principle of the very ancient remedy for rheumatism, 'Oil of Wintergreen'. Salicylic acid was introduced into Internal Medicine in 1873 and its derivative, Aspirin, in 1899. Both drugs are of great importance, and many other derivatives of Salicin are in use. Salicin and its derivatives can be prepared synthetically, and the synthetic products are in use in Medicine.

Of all the glucoside-yielding plants, perhaps medically the most important is the Foxglove, *Digitalis purpurea*. The use of the plant was known to some of the medieval herbalists, and is, moreover, recommended in the German and English printed herbals of the sixteenth and seventeenth centuries. Foxglove is mentioned as a folk remedy in George Eliot's *Silas Marner*, the story of which refers to a period round about 1750 before the Industrial Revolution, 'when the spinning-wheels still hummed busily in the farm-houses' (Fig. 89). It was introduced into scientific Medicine in 1785 by William Withering (1741–99) of Birmingham in his *Account of the Foxglove*, which gives details of numerous cases treated with it.

Digitalis long resisted the attempts to extract an active principle, but since the seventies it has yielded to investigators a whole series of glucosides. Digitalis and its derivatives have become of much importance, especially in the treatment of cardiac conditions. Despite the success in obtaining glucosides from the Foxglove, the extract of the plant itself continues in wide use.

(e) *The Study of Pharmacology.*

Since the middle of the nineteenth century the investigation of the physiological action of drugs has been mainly in German hands. The most prominent exponents of the method have been Karl Binz (1832–1912) and Oswald Schmiedeberg (1834–1921), both professors at Dorpat, where there has been a pharmacological laboratory since 1849. The first pharmacological laboratory in America, that at Ann Arbor established in 1893, and the first in England, that at

University College, London, established in 1905, were successively occupied by A. R. Cushny (1866–1926). The work of these and of other pharmacologists has not tended to increase but to reduce the number of drugs. Nevertheless, some new drugs of great importance have been introduced by them. Of these, among the more valuable is Amyl nitrite, the inhalation of which was first recommended by T. Lauder Brunton (1844–1916) as early as 1867 as a remedy in certain cases of sudden heart seizure.

Improvements have been made not only in the drugs themselves but also in modes of administration. The ancient methods of inunction and inhalation, as well as other older methods, have been greatly elaborated in modern times, and are now of wider application than they were. No advance of this order compares in importance with the introduction of the Hypodermic Syringe by the ingenious French surgeon Charles Gabriel Pravaz (1791–1853). By means of this instrument various drugs can be injected directly into the subcutaneous tissues or into the veins. This mode of administration is more accurate and under better control than any other, and the action of the drug so injected is swifter and more sure.

(f) *Chemotherapy.*

During the twentieth century the outlook on drug treatment has been modified by the success obtained in the *specific* treatment of certain diseases, that is to say, treatment by remedies which strike at a particular disease and no other. Until quite recently scientific Medicine recognized very few specific remedies. It

had been ascertained that Cinchona owes its value in Malaria to the alkaloid Quinine (p. 326), which acts as a specific exterminator of the malaria parasites, and not simply as a remedy for fever in general. It had also been ascertained that Ipecacuanha owes its value in tropical Dysentery to the alkaloid Emetine, which acts similarly as a specific exterminator of the protozoal organisms which are the infective agents. Quinine and its allied alkaloids and Emetine and its allied alkaloids were practically the only specifics the value of which had been scientifically proved, except Mercury for Syphilis.

About the beginning of the twentieth century arose the new 'Chemotherapeutic' movement as it came to be called. This movement was initiated by the studies of natural Antibodies (p. 262) by Paul Ehrlich of Frankfurt (1854–1915). Antibodies are strongly antagonistic to the parasitic organism the toxin of which has elicited them, but, on the other hand, they are quite harmless to the animal body in which they reside. Here are ideal remedies provided by Nature herself. Ehrlich compared them to magic bullets, constrained by a charm to fly straight at their objective and to injure no other. No such perfect artificial drugs have yet been produced. The problem of Chemotherapy is rather how to poison the parasite as much as possible while poisoning the host as little as possible.

When Ehrlich began the study of Chemotherapy observers had long known that certain aniline dyes have a special affinity for certain cells or organisms. Indeed the affinity of certain of the dyes for certain bacteria had made possible the work of Koch on Tuberculosis and on other diseases. As far back as the seventies and

eighties much work had been done on the subject, and the action of these dyes had interested a large variety of investigators. Ehrlich's first results were on a protozoal parasite, which infests dogs. By injecting small doses of a certain aniline dye into the veins of the infected animal it was found possible to destroy the parasites while doing very little injury to the dog.

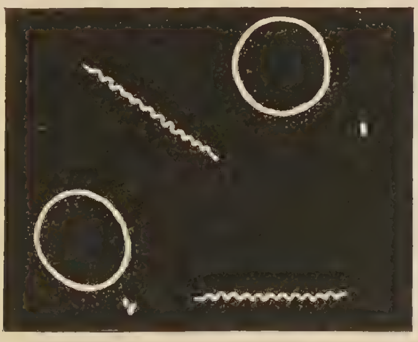


FIG. 133. THE ORGANISMS OF SYPHILIS IN A SMEAR FROM THE LOCAL INFECTION. Highly magnified. They are best seen by means of a special optical arrangement in which the outlines of the objects appear glistening white and the background black. The round objects are pus corpuscles, the two spiral objects the organisms of syphilis.

At this point Ehrlich turned aside from the aniline dyes to study the effects of much more toxic substances. He selected the compounds of arsenic for the purpose. After prolonged research, he obtained an arsenical derivative which proved very toxic to parasitic protozoa and little toxic to their animal hosts. When a vast number of experiments had been made, this substance was tried in 1910 in cases of human Syphilis. This disease had been shown by Fritz Schaudinn (1871–1906) in 1905 to be due to a protozoal parasite, the *Spirochaeta pallida*

(Fig. 133). The results obtained by the new remedy were very satisfactory and a valuable specific was thus added to the medical armoury. The drug became widely known as 606, since this is its number in the series of the arsenic derivatives with which Ehrlich had experimented. In the meantime others had been at work along lines suggested by the aniline experiments. Their investigations led in 1920 to the discovery of a specific against the deadly *Sleeping Sickness* or *Negro Lethargy*. This drug is known as *Bayer 205* from the firm that prepared it and the number in the series of substances that were tested.

Since the first preparation of 606 and 205 some interesting facts have emerged concerning their action as well as the action of Quinine, Emetine, and other specific remedies. It has been found that the toxicity of these substances to the parasites against which they are aimed is much greater when the parasites are within the body than when the drugs are applied to the organisms outside the body. In other words, the drugs do something to the body, or the body does something to the drugs, that is inimical to the parasite. The nature of that something is still under discussion. In the case of Quinine it seems that the Quinine so affects the red blood corpuscles that the malarial parasites cannot enter them and so cannot go through their sexual cycle (Fig. 123). Thus the Quinine does not act as a direct poison but attacks the parasite in a much more subtle manner. In the case of other parasites the action of the specifics is more difficult to understand. It should be pointed out, however, that the chief victories of Chemotherapy have been in dealing with the protozoal

rather than the bacterial diseases. A main task of future Medicine will be the discovery of means of eliciting antibodies against the various bacterial infections. For this there is more immediate hope from the use of remedies of vital origin than from those synthetically produced.

§ 21. *Interpretation of Collective Medical Data.*

The drawing of a deduction of scientific value from experience is by no means a simple process. In many sciences the investigator has the power to control experience; in other words he can *experiment*. But even the interpretation of experiment needs special precautions. The physical experimenter must, for instance, make sure that he has but one 'variable'. Thus, if examining the effects of pressure on a gas, he must see that in raising or lowering pressure he is not altering temperature, or if recording the effects of temperature he must satisfy himself that he is eliminating those of pressure. In experiments upon living things the limitation of the field of action to one simple factor is often—perhaps always—impossible. The biological investigator is therefore accustomed to accompany his experiment with 'controls'. Thus, if he wishes to ascertain the effect on the growth of animals of feeding with milk that has been boiled, he must feed one series of animals on unboiled milk while he is experimenting with a series fed with the boiled milk. He must take steps to ensure that the two series are similar as regards age, strength, size, &c., and that the conditions under which they live are identical, except as regards the one factor the results of which he seeks to ascertain.

When the observer is dealing with human material, it is very seldom that he can either restrict the number of variables to one or secure an adequate series of controls. Physicians are habitually in a position in which action of some kind is demanded. They cannot await the conclusion of laboratory researches, which may extend over years, for the patient must be relieved at once or die. Being often unable to use those most reliable instruments of science, experiment or observation under control conditions, physicians have come to rely on what is called 'a general experience of disease'.

One of the commonest fallacies of such general experience is assignment of causative relationship between two conditions, simply on the ground that they frequently occur in association. Thus it is a fact—and one to which attention has been drawn by medical observers—that rheumatic affections and red-headedness are often found together. But both conditions are common and it has not been satisfactorily demonstrated that the association of the two is any commoner than their frequency in the population at large would render probable. Such general experience is therefore very fallible and is incapable of scientific expression, though it is often very valuable and sometimes indeed entirely indispensable. To give such experience scientific expression, to place it in terms of the 'primary qualities' of the founders of modern Science (pp. 106–7), it is necessary to put it into statistical form. Statistical statement thus becomes of the highest importance for medical progress. Medical statistics, when prepared from proper material and drawn up with the requisite skill,

are at once the most exact and the most generalized expression of medical experience.

Statistical statements, however, vary greatly in their value and ease of interpretation. The simplest statistical statements with which the medical man has to deal

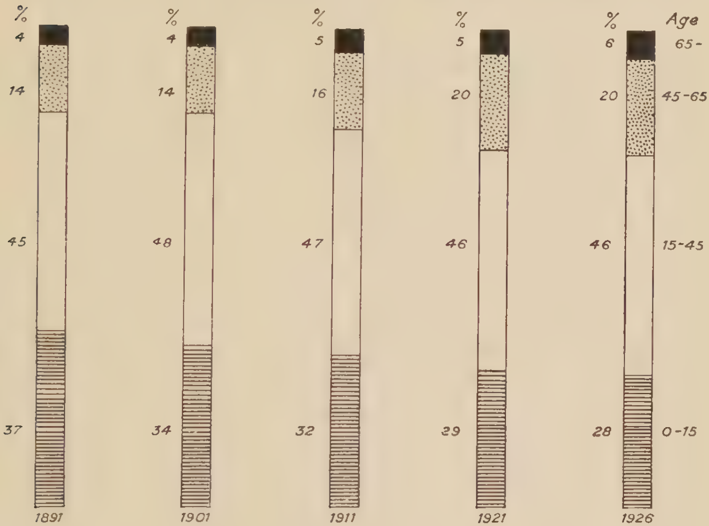


FIG. 134. DIAGRAM ILLUSTRATING THE ALTERATION IN THE PERCENTAGE OF AGE-DISTRIBUTION OF THE POPULATION OF ENGLAND AND WALES FROM 1891 TO 1926. It will be observed that the people of England and Wales have been getting steadily older.

are perhaps those which relate to surgical operations. The categories in which the patient may be placed are here limited; he may die, recover, improve, or get worse. If the operation is a quite simple one, and if the surgeon is perfectly honest, and also—which is rarer—quite unbiased, a small body of statistics may carry immediate conviction as to the value of an operation.

Thus, Lister's first results with amputation, as obtained under his antiseptic conditions, at once satisfy the mind, although the conclusions are based on only forty cases (p. 240). No surgeon at once both able and willing to appreciate these results would hesitate to adopt the new method.

The operation of amputation is, however, in a statistical sense, a particularly simple matter. The patient must either undergo the operation or not, and the proportion of cases in which the necessity is doubtful is very small. Further, he either recovers or dies—for the operation could hardly be in itself unsuccessful, nor the surgeon in doubt as to whether the patient had recovered or not. Many operations, however, are not of this order. They may be performed for conditions as to the exact nature of which the surgeon is uncertain, and for symptoms which may be only partially relieved. Thus, the removal of the appendix for Appendicitis may be most urgently necessary for the saving of life in one case and may be a matter of convenience for the relief of more or less indefinite symptoms in another. Further, what one surgeon calls appendicitis another may not. One surgeon may have every appendix that he removes submitted to skilled pathological examination before he accepts the case as one of appendicitis and places it among his statistics. Another may be quite content with naked-eye appearances of the nature of which he alone is witness, judge, and reporter. It is, therefore, clear that any collective statement as to the results of such an operation must be cautiously scrutinized before conclusions of the slightest scientific value can be drawn from them.

There is a common and rather foolish saying that 'Statistics may be made to prove anything'. This is true, but it is true only in the sense that *evidence*

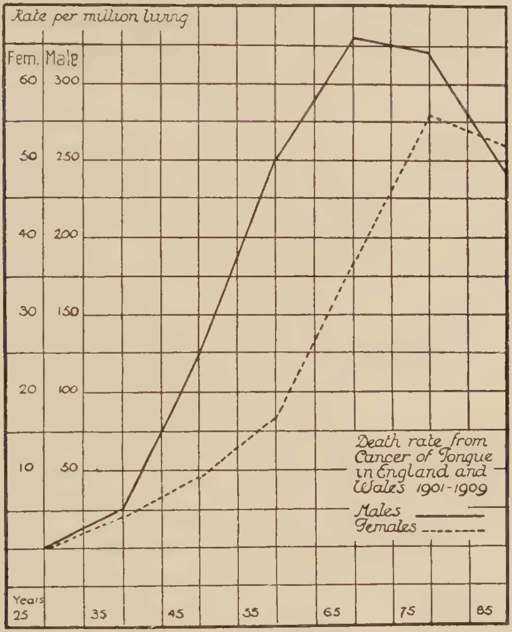


FIG. 135. DEATH-RATE FROM CANCER OF THE TONGUE. It will be observed that it is not a common cause of death till about 45 years of age, but that it then increases rapidly to fall again in both sexes in old age. These features are clearly related to various factors in the causation of the condition. One of these is certainly Syphilis, which is most frequently contracted between 20 and 30 and more often by men than women. The so-called 'tertiary' effects of this condition, some of which lead to Cancer of the Tongue, do not usually make themselves felt, however, for many years after infection. Contrast Fig. 136 and Fig. 137.

may be made to prove anything. The matter turns on the questions, firstly whether the evidence is of a good or a bad order, and secondly whether the investigator is in a good or bad position to interpret the evidence.

A statistical statement may be well or ill founded and well or ill interpreted, but statistical statement is, in

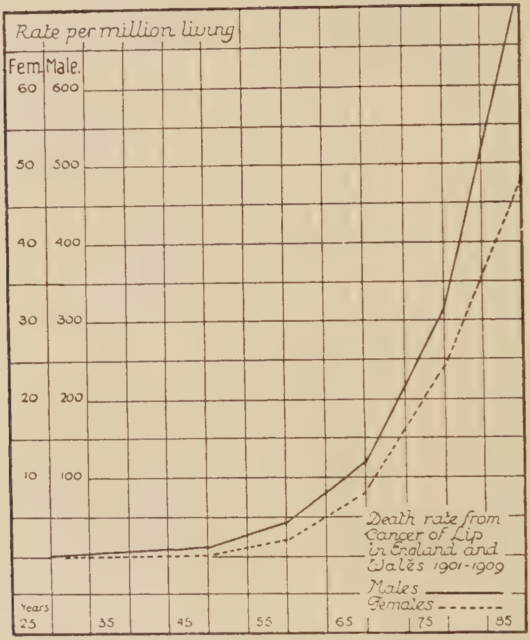


FIG. 136. DEATH-RATE FROM CANCER OF THE LIP. It will be observed that this curve resembles in form that of the death-rate from Cerebral Haemorrhage as shown in Fig. 137, but differs from that of the death-rate from Cancer of the Tongue as shown in Fig. 135. The chances of dying from Cancer of the Lip are negligible till middle age is past and then increase progressively throughout life. In the causation of Cancer of the Lip Syphilis is not an important factor. On the other hand the continuous irritation of pipe-smoking, which acts not at one age but throughout life, has to be considered as a causative element. Hence the resemblance to Fig. 137 rather than to Fig. 135.

fact, the only scientific method open to us for presenting long series of data. The conclusions to be drawn from those data, though sometimes evident and easily

elicited, at other times demand specially skilled and specially trained interpreters. Moreover, to be of value to others, such interpreters must also be skilled in expression, so that the main body of those who have no statistical training may be in a position to understand the essential elements in their conclusions. In no medical department is literary power of greater importance than in that which deals with statistics. Thus has arisen the small but highly important class of medical statisticians. The rise of medical statistics into a vocation places the crown on Medicine *as a science.* It is not given to many medical men to be proficient in this department. But the duty lies on all medical men, and indeed on all citizens, to appreciate the value of this study and to seek to appraise its simpler and more established conclusions.

It is remarkable how frequently a straightforward statistical statement may remove a false impression, even when the impression is based on evidence not of a wholly unscientific character.

For example the increase in the incidence of deaths from Cancer has often been emphasized. But Cancer is a disease of advancing life. The age distribution of the death-rate from many forms of Cancer is closely parallel to that of certain other forms of senile disease (Figs. 136–37). Now the age constitution of the population of most civilized countries is altering in the sense that the proportion of the elderly and aged is constantly increasing (Fig. 134), so that some increase in the Cancer incidence must be expected. Moreover the appearance of some increase in the incidence of Cancer is due to improved diagnosis. How far there is a

real increase, when these factors have been taken into account, is still somewhat doubtful. It must always be

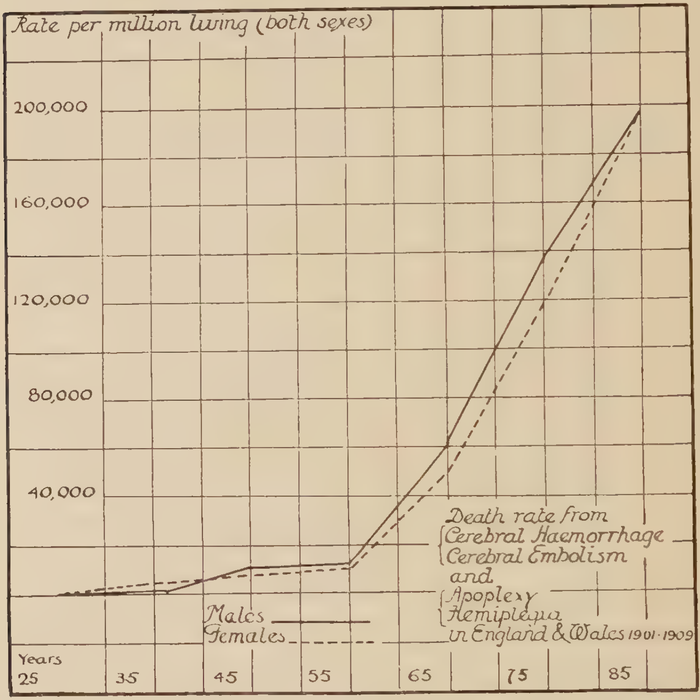


FIG. 137. CHART OF DEATH-RATE FROM CEREBRAL HAEMORRHAGE AND ALLIED STATES. These conditions are extremely rare in the young, but among the commonest causes of death in later life. The liability to them increases progressively to extreme old age. This is explained by the fact that Cerebral Haemorrhage etc. follows on the rupture of a blood-vessel in the brain and the rupture of the vessel is conditioned by the hardness and brittleness of its coat. The hardness of the arteries increases progressively in later life, whence the saying 'a man is as old as his arteries'.

borne in mind that a relative decrease in the proportion of deaths from *any* cause must automatically increase the proportion of deaths from other causes.

Again, there is no doubt of the fall in the death-rate in England and Wales from 'Phthisis', or pulmonary tuberculosis, during the last fifty or sixty years. There is also no doubt of the effect both of bad housing and of urban conditions in inducing a susceptibility to chest disease in general and to pulmonary tuberculosis in particular. Further, there is no doubt that the rural population suffers less from pulmonary tuberculosis than the town population. These matters of common medical knowledge have naturally led to the conclusion that the rise of the great towns has led to a great increase of pulmonary tuberculosis, and that this increase has been remedied by the improved housing and sanitary conditions of the last generation. A study of the statistical evidence, however, negatives this view. The rise in the proportion of deaths from pulmonary tuberculosis took place before the Industrial Revolution. Moreover, the proportion began to fall long before the campaign against tuberculosis could affect the issue. The history of pulmonary tuberculosis may, in fact, be regarded as that of an 'epidemic' outbreak, extending over about 100 years, of a disease which has always been endemic and remains so now that the epidemic is past.

These points are well brought out in the accompanying diagram (Fig. 138). The fall in the proportion of deaths from Phthisis expressed there gives rise to further considerations. It might seem that the statement that the proportion of those who died from phthisis was diminishing left in itself no doubt that the disease was less prevalent than formerly. This, however, is not the case. Phthisis is more liable to affect

those under forty-five years of age than those who are older. Now the proportion of the population that is under forty-five is steadily diminishing (Fig. 134). This is one of the results of the steadily diminishing general death-rate (Fig. 96, p. 196). Therefore the proportion of the more susceptible to the less susceptible is diminishing. It might have been the case (though it is not) that the ratio $\frac{\text{more susceptibles}}{\text{less susceptibles}}$ was not only decreasing but was actually decreasing more rapidly than the ratio $\frac{\text{total deaths}}{\text{deaths from phthisis}}$. Had this been so, the conclusion would have been justifiable that the fall in the proportion of deaths from the disease did not correspond to any decrease in its infectivity. In fact, however, the prolonged high mortality from phthisis and its later rate of fall do suggest the former prevalence of a more virulent type of the disease over a long period, in other words something of the nature of a prolonged epidemic.

This conclusion leads us to the conception of the nature of an epidemic. To gain some conception of the ideas involved in that word, we must glance back in history.

From the time of Hippocrates onward the subject of Epidemic outbursts of disease has drawn the attention of physicians. A writer in the *Hippocratic Collection* thought he could perceive an association of symptom-complexes with each other and with the weather. In the great work *Epidemics*, to which the name of the Father of Medicine is attached, such a view, known as that of 'Epidemic Constitutions', is set forth. The view was revived by Sydenham in the seventeenth century

and has given rise to a vast literature extending to our own time. In the eighteenth and nineteenth centuries the attempts of the investigators of vital statistics to place the leading events of life in a form capable of exact analysis (pp. 166–68) focused attention on the search for a mathematical expression for the rise and fall of epidemic diseases.

The first successful attempt to describe epidemics

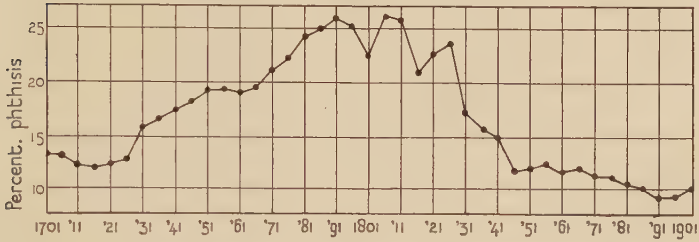


FIG. 138. CURVE SHOWING PERCENTAGE OF DEATHS FROM PHTHISIS to total deaths from all causes in London over a period of 200 years. It will be seen that the percentage begins to rise definitely about 1730 and to fall definitely about 1830. This state of affairs may be pictured as an epidemic lasting about 100 years.

along these lines was made by William Farr (1807–1883), an official in the office of the Registrar-General in London, and one of the greatest of all epidemiological thinkers. His first publication on the subject was in 1840, and had reference to the recent outbreak of small-pox, in which more than 30,000 had died in England and Wales. It was his merit to observe that the successive decreases in the number of cases in successive equal periods during the decline of the epidemic correspond to the successive increases in the number of cases during successive equal periods of the rise of the epidemic. In other words, he observed

that the rise and decline of an epidemic tend to be mathematically symmetrical.

Farr's suggestion that epidemics are liable to follow the lines of regular mathematical rules drew little attention at the time, but in a later year it led to a most remarkable and striking prophecy. At the end of 1865 Cattle-plague broke out in England. Week by week the number of cases increased. In the fourth week of February 1866 the responsible Minister, in a speech in Parliament, gave a very gloomy account of the state of affairs, expressing the belief that the devastation would be far beyond what had yet been encountered. Farr, however, had been watching the returns, and had been applying his rule to them. He thereupon made a public pronouncement of his belief that at an early date the outbreak would reach its maximum and would then decline. The outbreak did, in fact, very closely follow the course which he had predicted by reasoned calculation. Farr even prophesied the number of cases that would occur week by week. His prophecy was near the truth.

During the years that followed Farr's prediction his views were applied with success to a variety of epidemic conditions. The regular form of the development of the epidemic was found to apply in certain outbreaks of typhus, measles, and other conditions.

Farr's law was more exactly expressed by him in 1868. It remained, however, simply a mathematical law, a rule of which the underlying cause was not apparent. It was soon observed that his law applied to many but by no means to all epidemics. Moreover, it was perceived that the actual figures which he gave for

his epidemic of 1840 resembled those of certain other epidemics in that they could be fitted with greater or less exactness to a well-known mathematically described curve, known as the 'normal curve of error'. We need not discuss the mathematical foundation of this curve, which is shown in two variants in Fig. 139.

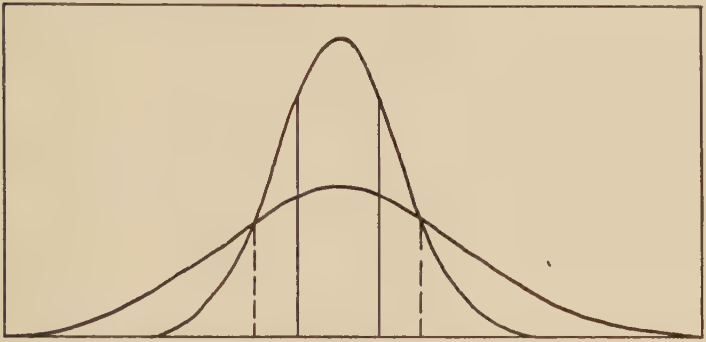
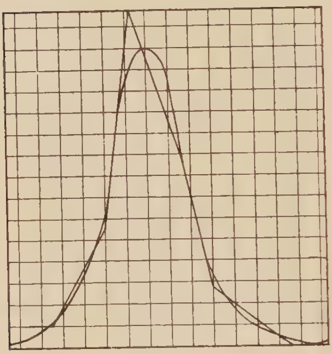


FIG. 139. THE NORMAL CURVE OF ERROR, shown in two types made with the same formula but with different constants. This curve has been shown to be similar to that representing the incidence of cases in some Epidemics. Vertical lines are drawn from two pairs of symmetrical points. The continuous lines refer to the higher curve, the broken lines (from the points of intersection of the two curves) refer to the lower curve. The lines will be seen to divide the curves into three parts. This division is of such a character that the sum of the two lateral areas is equal to the central area for each case.

For our immediate purpose it is enough to observe that it rises gradually at first, but then more steeply, that the steepness decreases after a while, and then the curve begins to decline again, as it rose. We note that it is symmetrical.

When we are dealing with living beings we are dealing with things that may indefinitely approximate to a mathematical rule, but never entirely fit it. Especially

when the living beings are also human beings, with their infinitely complex relationships, various factors are present which interfere with the exact application of mathematical findings. Nevertheless, the theoretical form of the epidemic is an extremely useful framework



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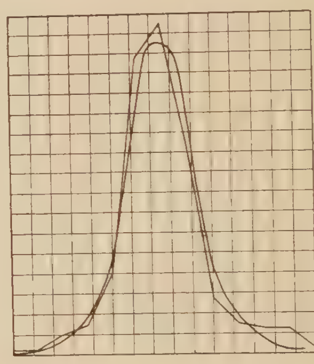

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FIG. 140. Curve of monthly number of deaths from Small-pox during an epidemic at Warrington, Lancashire, in 1743.

FIG. 141. Curve of weekly number of cases of Scarlet Fever registered during an epidemic at Glasgow in 1892.

Both curves are fitted to the theoretical epidemic curve, and are modified from Brownlee. The curves are in both cases explained on the assumption that the infectivity, having reached a high point at the beginning of the outbreak, decreases thenceforward in geometrical progression.

into which actual epidemics may often be fitted, with greater or less exactness. In the accompanying figures (Figs. 140–41) are adduced cases of greater exactness. There are, however, many cases in which an 'outbreak' does not seem to fit the simple theoretical curve at all. Examination of such curves has in some cases suggested that we have not one epidemic or disease but

two or more to deal with. In some cases it has been possible to analyse the outbreak on the basis of two

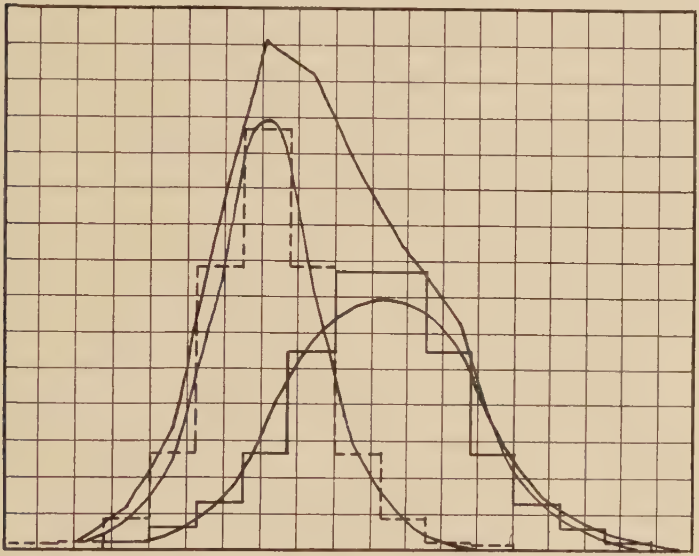

FIG. 142. THE CURVES OF SOME EPIDEMICS, which do not follow the theoretical curve, may be analysed as compounded of two or more epidemics, each of which accords individually to the mathematical rule. Thus 'Summer Diarrhoea' is a seasonal disease very fatal to infants in England during the hot months, July and August. The angular curve shows the average daily incidence of deaths from this disease in London during the fifty-three years 1850–1903. It can be analysed into two of the theoretical epidemic curves.

Each reading of the curve, calculated from the actual cases of 'Summer Diarrhoea of Infants', can be divided into two, as indicated in the step-like readings, one dotted and the other continuous. These accord beautifully with two theoretical curves, thus indicating not one but two recurrent epidemics. It thus seems probable that two separate sources of infection are confused as 'Summer Diarrhoea of Infants'.

or more theoretical curves, suggesting in fact two or more outbreaks of similar but not identical causation (Fig. 142).

What can be the causative element which constrains the incidence of a disease in a population to follow mathematical rules? An answer was provided by John Brownlee (1868–1927), the late statistician to the Medical Research Council of England. The leading fact about an Epidemic is that it rises to a maximum, falls, and then dies out, and that the curve representing the number of new cases in a series of equal and consecutive periods of time throughout the Epidemic is symmetrical. In practice the decline is usually a little slower than the rise. This is sometimes, at least, due to better observation and record of the later cases. Now why does an Epidemic die out? The possible reasons may be reduced to three. Firstly, the end of an Epidemic may be due to the exhaustion of susceptible persons in the population. That is to say, all the survivors are immune, either being so by nature or having become so by having contracted the disease and recovered. Secondly, it is conceivable that the liability to the disease should be decreased, not by rise in the proportion of immunes, but by externally acting causes, as, for instance, by rise of seasonal temperature, which would provide conditions under which the organism loses its infectivity. Expressed in older language, this is to say that the 'Epidemic Constitution' (p. 342) has changed. Thirdly, the infecting organisms may, of their own inner nature, lose their infectivity. The second factor may act in special cases, but may be disregarded except in those cases. We are, therefore, left with the first and third.

Now it is possible to construct curves that would correspond to the exhaustion of the supply of suscep-

tible persons by continuous increase of the proportion of those who become immune either by taking the disease or by dying. These curves, however, have the character that their descent is more rapid (and neither as rapid nor less rapid) than their ascent. It is the merit of Brownlee to have suggested that the actual curve of the Epidemic corresponds to a known though very little understood biological phenomenon, namely change in the infectivity of the invading organisms. The simplest expression of his discovery is that the loss of infectivity of these organisms is approximately in the ratio given by a geometrical progression. That is, if the infectivity of the Epidemic be m, and at the end of a unit of time mg (when g is less than unity), at the end of a second unit of time it will be mg^2, and at the end of the third mg^3, and so on. Assuming this to be a fact, the course of Epidemics would follow the curve of normal error (Fig. 139).

Of late years it has been possible to institute artificial epidemics in a series of animals under control conditions. Such experiments must, in the nature of the case, cover a large number of years, but they bid fair to throw much light on the nature and progress of human epidemics.

These results seem to show, what was believed on other grounds, that in the case of highly infective disease, to which, in any population, there are many highly susceptible, isolation of declared cases has little or no effect on the course of the Epidemic. Such diseases are Scarlet Fever, Measles, Influenza, &c. Moreover, the experimental epidemics seem to confirm the conclusions of Brownlee that in some cases at least

the course of the epidemic is determined by biological changes within the parasitic beings that cause the epidemics.

Thus in the end our health, our lives, and indeed the continuance of our civilization may well depend upon a factor which is outside ourselves. For reasons which we know not, the pullulating billions of living things which are around us, upon us, within us, take up a virulence which before they had not, and after a time they lose that virulence to become as they were before. The world is devastated by an outbreak of Plague, of Cholera, of Influenza. But how and why the organisms that carry these diseases should acquire a new and more deadly infectivity lies among the secrets yet locked within the living cell. Life—the life of the Cell, of the Bacterium, of Man himself—remains among the *Arcana Naturae*. These are the secret things that in their essence—which is Life—remain and will remain behind the veil. From such cells we came, through such cells we shall return. As to what is the force which starts these processes on their way, we are as ignorant as children, and must remain so, in essence, till we understand the nature of the processes of coming into being and passing away. So Medicine must end where she began, quaking before the Mystery of Life, a Mystery which could only be resolved if we could express Mind in terms simpler than itself. If this could be done the veil that is cast over all flesh would indeed be rent. But the author of this work believes that the hope of this is vain and that we are here in the presence of one of the ultimate things.

EPILOGUE

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WE have now traced various movements in Medicine throughout the ages and have seen how all the sciences in turn have been made to bring their tribute to the alleviation of suffering. We have seen especially how the consideration of disease as a whole, and of the health of peoples as a whole, has introduced a new view in the handling of disease. Health is a public asset, and its promotion has now been recognized as a public duty. There are undeniable disadvantages in placing officers of the State in control of the personal liberties of its citizens, but, on the whole, the advantages, in matters of health, have outweighed the disadvantages. Only a professed pessimist or a crotchety reactionary could deny the gains to humanity from the passage of preventive measures from private into public hands.

There is another side of the picture which we have need also to consider. The advances in Medicine and the advantages that have accrued therefrom have been entirely the result of the application of the rational method of observation and experiment. To control Nature we must above all things understand Nature. Neither the conception of Nature as the kind old nurse nor the conception of Nature ravening red in tooth and claw will stand. Least of all can we tolerate the picture of Nature as a bountiful mother. If we go to her asking something for nothing, she (far from bountiful) will give us little but what we have given her, and to him

who but begs she gives no more than a beggar's portion. It is thus that she has served the magician and the wizard, who think they can compel her to give them all things by their paltry charms!

The amount of human labour and ingenuity that is now being thrown into the investigation of Nature is almost incredible even to men of science. Some conception of the enormous and unreadable bulk of scientific literature may be gained by a glance at the *International Catalogue of Scientific Literature*. This gives the *titles alone* of original articles in the various departments of physical science. These titles for the year 1914 alone occupied seventeen closely printed volumes! The rate of publication has accelerated considerably since then. There are now about 25,000 periodicals devoted to scientific publications! There are very few departments of science which do not have some bearing on Medicine. It is evident that no human mind can possibly compass even a year's output of this material.

And yet it is not the bulk of writing on Science that forms the only or even the chief deterrent to the general comprehension of its principles. The mass of scientific detail has always been beyond the power of one mind to grasp. But as we have traced Rational Medicine through its long course in Antiquity and the Middle Ages to its debouchment on to our own time, we have found not only a more difficult but also a new situation. In approaching our own age we have found ever more difficulty in discussing Rational Medicine as a single channel of thought. It spreads into a Delta, of which, though the many mouths may inosculate, yet the tendency seems to be for an ever wider divergence. This diffusion,

induced by increased specialization, cannot go on for ever without defeating the very objects for which specialism was invented.

On the other hand, when we glance at the tasks now being performed by the medical man, we cannot fail to be struck by the great increase in the number of things that have come to be regarded as within his sphere. It is a commonplace that he has in large part taken the place of the parson. But he has also made encroachments on the functions of the lawyer, the legislator and the judge, of the schoolmaster, the architect and the statistician. He has assumed some of the duties of the parent and guardian, while even the soldier and the policeman are to some degree under his control. In the ordering of their lives, and even in the regulation of their vices and the reform of their shortcomings, men and women are far more willing to seek the advice and help of the medical man than once they were. The reason is, without doubt, that his advice is much more worth having than it once was.

The organization of research, the systematized record of experience, the improved intercommunications of our time, have combined to increase vastly the medical man's sources of information and to make his application of them more accurate and more scientific. Moreover, there are factors in our social life itself that have tended not only to deepen the physician's knowledge but to widen his experience. His effective working-day has greatly lengthened. No doubt, the motor car and railway train are important elements in this extension of the doctor's day, but a far more fundamental element is the advent of the skilled nurse. Many tasks which

occupied the time of the doctor in the old days are now relegated to her. The result is that the doctor sees a far greater number of patients and has a much greater experience of actual sickness than was formerly possible.

But after we have discussed all those factors which have gone to the increase of the power of Physic we have still to consider the philosophical basis which has conditioned this increase. Men do not willingly accept that in which they do not believe. The shifting of men's trust implies a shifting in their faith. In truth the triumph of Physic has underlying it a subtler triumph, that of Scientific Determinism. The great increase in the detailed knowledge of Nature has led to a great increase in the belief in the Reign of Law. Disease and death were once thought to be the special acts of Providence. They are now widely held to be illustrations of determined natural laws. Men of science in general, and medical men in particular, are not wont to profess themselves philosophers, but, in fact, much of their work is done in a spirit which would have us believe that these determined laws are universal and are wholly outside ourselves. Has there not arisen a school that would claim that our thinking is but a seeming, and that we do but behave as though we thought? Three centuries ago Descartes conceived that the animal might be treated as a machine. If man be but an animal, consequences are entailed from which Descartes shrank, for the watchword of his philosophy was 'Cogito, ergo sum', *I think, therefore I am.* There is a newer school whose work is intimately bound up with the progress of Medicine that would abandon this basic doctrine of the father of

modern Philosophy, who is also the founder of Physiology, as a separate discipline.

The position as it stands appears as a dilemma. The triumphs of Science have been secured by disregarding Mind, and yet they cannot be appreciated or advanced without invoking Mind. Unless we accept the full conclusions of the Determinist Philosophy, we are forced to the conclusion that Mind must do something to the animal body. If Mind holds the reins, there must be a point at which Mind pulls the reins. The matter ever in dispute is where that point may be. If life and growth are bound up with an Entelechy, as seems to the author of this work to be the case, there must somewhere and somehow be a level in the organism at which the laws of physics and chemistry are transcended by some other mode of action.

It is no part of our task to provide a Philosophy which will resolve all the problems that our subject raises. Nevertheless, in the presence of this dilemma, such a work should not close on too optimistic a note, in the department either of medical thought or of its application. Even if looked at merely as an interpreter of its own terms, determinist thought, which lies at the basis of modern medical developments, has not been quite so universally successful as is often supposed, and as the preceding pages of this book may lead the reader to think. While enormously increasing the sum of our knowledge of Nature, it has also tended more and more to separate the parts of that knowledge from each other. It is clear that no such way of thinking can ever give us a survey of Nature as a whole. It can never enable us to 'think things together', and without

such thinking together our life is and must remain a contradiction and a muddle.

For a real survey of Nature we must look to another Philosophy and another Method. We are in this matter but just entering on a new era, and may it not be that some sort of solution will be provided by a better study of the Mind itself? Only by our minds can we know that Nature presents us with any order at all. It therefore behoves us to search out most diligently all that we can learn about our minds, to see whether, on the one hand, this determined order, which has so impressed our age, is in any degree within us and part of our observing instrument, or whether, on the other hand, it is wholly without us. There is much evidence that it is not wholly without us, and that Determinism is a habit in our method of thinking on certain topics, and that the emphasis on the 'primary qualities' (see pages 106–8) which we inherit from Galileo is by no means justified. It may be that what we think and feel and see is not only as real as what we weigh and count and measure, but that weighing, counting, and measuring are but forms of thinking, feeling, and seeing. In this connexion the reader should turn over again in his mind the implications of the 'Law of Specific Nerve Energies' enunciated by Johannes Müller (see pp. 212–13).

Nor must we end on too optimistic a note as to the actual achievements of Science. Advances in our knowledge have certainly been very great, but they may be and often are exaggerated. We must always guard ourselves against considering only mere accumulation of detail as an advance. The collection of data is but a means to an end, and if that end is not reached

they are a very weariness and vexation of the philosophic spirit. Real advance in knowledge can only be tested by effective advances in theory, and thus judged the cost of progress—the cost in the brute accumulation of facts—has increased far more rapidly than progress itself. What is wanted is not so much new data as correlation in their accumulation. The increase in medical specialism is not so much evidence of advance as it is of the heaping up of uncoordinated observations.

Works on Medicine intended for popular consumption are often couched in the jubilant terms of victory. Yet there are whole departments in which no progress whatever has been made. We pride ourselves on the advance in knowledge of infectious disease which the germ theory has brought us, and yet we are utterly and completely ignorant of the two things about infectious disease which are the two things most worth knowing on that topic. Firstly, no man has conceived the way in which the parasites of disease first fastened themselves on the animal body, a specific parasite to a specific animal. In other words, we have not the least idea how diseases first begin. Secondly, no man has conceived a reason why diseases, distributed over a wide area and in many bodies, should vary in virulence from time to time, why, for instance, a relatively mild condition, such as influenza, should suddenly devastate the world. It is easy to say that human resistance varies, but that is only to restate the problem in terms of which we know nothing. On these high topics of Medicine we know as much and as little as Hippocrates.

Moreover, if we turn to definite diseases, there are

many conditions, and those among the most important, of which our ignorance is almost complete. Thus of the very common and painful diseases, muscular rheumatism and rheumatoid arthritis, we know hardly more than Hippocrates and our remedies are but little more effective than his. The common cold—economically the most important of all diseases, not excluding Cancer and Tuberculosis—has a vast literature, but the physician is almost helpless in its presence and can but let it run its course. Measles, Whooping-cough, and Influenza have become more deadly of late years. We have still no clear line of treatment for them. Nor have we any real insight into the nature of Cancer. Those who reach advanced age have no better chance of life than they had two hundred years ago (p. 177). Above all, it must be remembered that the great majority of deaths are caused by diseases theoretically preventible. There is a natural term to life which it is desirable that all should attain. Yet most of us will surely die a violent death as truly as though struck down by a felon's hand. Death from disease is an unnatural and a violent death.

Faced by facts of this order there are those who constantly urge increased activity in medical 'research'. But research can only be prosecuted by those whose talents specially fit them for the work. With reason it may be and is doubted whether there are many in Western Europe or America who could profitably be employed on medical research who are not already so employed. It is easy to make investigations on a certain level, but those best qualified to judge are of opinion that the general level of medical research has fallen, not risen, of late years. The number of publications has

multiplied manyfold, but there are those who doubt if there is much increase in investigation of the first order. The increase in specialism and the extremely narrow outlook of some workers has stultified much investigation, since with his decreased range the researcher is often less able to perceive the bearings of his own work. Thus he may labour for years elaborating a technique by means of which he may collect facts without that guiding wisdom or judgement that is the mark of genius. It must ever be borne in mind that the object of fact-collecting is the deduction of law. Not all facts can be collected, for facts are infinite in number, and it is therefore necessary to select. Selection involves *judgement*, the final and indefinable property of Mind; for, if from the facts no laws emerge, the facts themselves become an obstacle, not an aid, to scientific advance.

All who have to read systematically large masses of modern scientific literature have been unfavourably impressed by its absence of form. It is evident that a large proportion of scientific workers lack adequate literary training and never acquire a proper sense of literary form. The growing interest in Science has had an unfavourable effect on Education in the direction of early and intensive specialization. The result is that many scientific publications are but semi-literate, they are often incoherent in presentation and even more frequently unnecessarily diffuse. Nor is it merely a matter of form. Language is but the outward and visible sign of which Thought is the inward and spiritual reality. Confused writing usually indicates and always leads to confused thinking. Thus the unliterary character of

scientific writing bids fair to pass from being a mere nuisance to become a great scientific evil. Good and effective writing implies a broad and solid literary background, just as good and effective scientific research implies a broad and solid scientific background. The fact is that the Humanities and the Sciences are far from being as independent of each other as many suppose. If literary studies lead to clear and effective expression and clear and effective thinking in the domain of Science, scientific studies ventilate and inform and vitalize Literature. The separation of the two disciplines, especially in the adolescent stage of mental development, does an injury to both. The concentration of the endowments of Learning on the scientific departments and especially on the departments of applied science has given rise to a very widespread evil which is none the less evil because it is subtle.

Within the sphere of the specifically medical sciences themselves there are tendencies which are open to somewhat similar criticism.

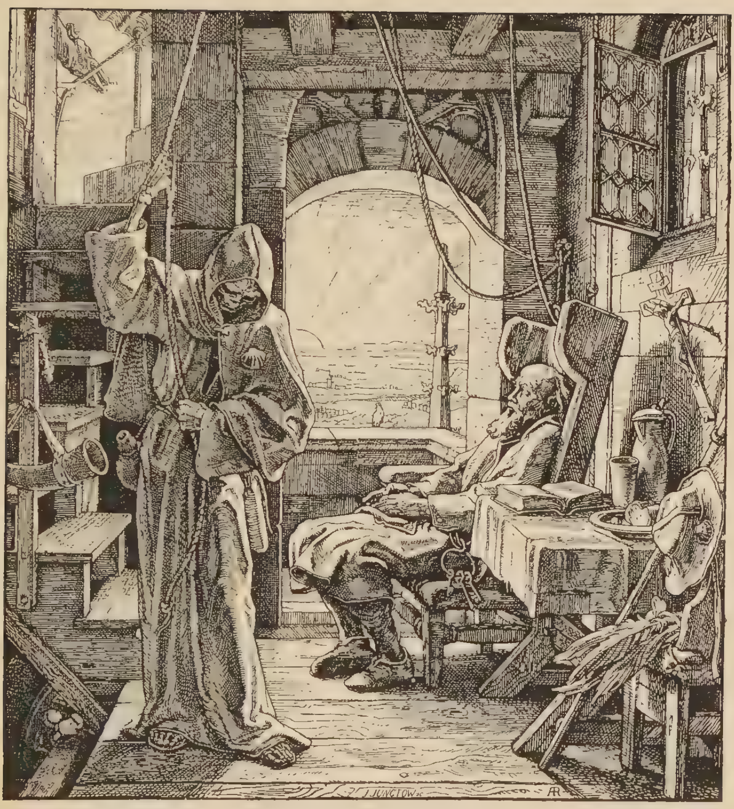
The great fallacy from which scientific Medicine has suffered in the past, and still to some extent suffers, is the 'direct attack'. We have come to look upon the animal organism as an immeasurably complex machine. For its elucidation knowledge from the most diverse quarters is therefore demanded. The physical chemist, the organic chemist, the physicist, the mathematician, the protozoologist, the systematic biologist, the botanist, the spectroscopist, the geologist, and a host of others are following callings which have no obvious bearing on the study of disease. Yet the results obtained by them, and by men of science in many other

departments, must be utilized in the study of disease. Our knowledge of health and of disease thus depends on the sciences as a whole—nay, on Knowledge as a whole. Those who would promote the health of mankind would do well if they sought to encourage not so much the medical sciences as Science as a whole, or rather Learning as a whole, for Science is a way of life which may penetrate into all departments of Learning, and is something far greater than those discrete accumulations of knowledge that we call 'the sciences'. The Sciences, working out their destiny, must in the end come together again.

If that consummation be reached we may expect improvement in health and prolongation of life to a degree greater than any previous ages have seen. We may indeed expect something yet better, for we may hope for a philosophy of the mind that shall make life better worth the living.

Medicine cannot give immortality, but it should enable us all to live out our full lives. Death, coming in due and not undue time, is shorn of all his terrors, when every man and every woman

> Shall come to his grave in a full age,
> Like as a shock of corn cometh in, in his season.
>
> *Job* v. 26.



FRIENDLY DEATH

INDEX